CHAPTER 2. Reference Method and Required Modeling Capabilities for Alternative Calculation Methods (ACMs)

The purpose and policy of this ACM Approval Manual is to specify the California Energy Commission approval process for Alternative Calculation Methods (ACMs) and the assumptions and procedures of the reference method against which ACMs will be evaluated. This manual encompasses the reference method and performance compliance requirements and procedures for nonresidential buildings, hotels & motels, and high-rise residential buildings. A separate ACM Approval Manual covers the performance compliance procedures and requirements for the remaining building types, primarily low-rise residential buildings. The procedures and process described in this manual are designed to preserve the integrity of the performance compliance process relative to a reference method. The reference procedures and method described in this manual establish the basis of comparison for all ACMs. In particular, the approval process described in this manual is designed to ensure that a minimum level of energy efficiency is achieved by all buildings complying with the building energy efficiency standards regardless of the Alternative Calculation Method (ACM) used. This is accomplished by having the ACM meet certain test criteria for a series of ACM/Reference Method comparison tests, by specific input and output requirements for all ACMs, and by vendor-certification of the ACM's conformance to the requirements in this manual. This chapter describes the reference procedures for use with the *reference computer program*, (the reference calculation engine), *version ~~86~~110 of DOE 2.1E* public domain computer program from the Lawrence Berkeley Lab, and the specific aspects of the reference method that are required for all ACMs.

In this manual the term "standards" means the building energy efficiency standards, Title 24, Part 6, Chapter 1 of the California Code of Regulations. The term "compliance" means that a building design in an application for a building permit complies with the "standards" and meets the requirements described for building designs therein. As indicated above, the term ACM stands for Alternative Calculation Method.

This Chapter specifies the reference procedures for the required capabilities that an ACM will be tested for and also specifies how the reference computer simulation program will be used to model the features. All of the required capabilities are described in terms of the capabilities and algorithms of the Commission's reference program. An ACM must account for the effects of all of the features described in this chapter on a building's energy.

The modeling procedures and assumptions for each capability are for both the *standard* and *proposed designs*. The requirements for the standard design include those that ACMs must apply to new features, altered existing features, unchanged existing features or all of the above. In order for a program to become certified, it must, at a minimum, accept all of the required inputs and meet the test criteria when compared against the reference computer program using procedures and assumptions as required in the sections describing the capabilities.

2.1 Compliance - Required Capabilities

2.1.1 Type of Project Submittal

ACMs must require the user to identify the type of project for which compliance is being demonstrated. These ACMs must require the user to choose one of the following options:

- New Building
- Addition Alone (modeled as new building but labeled on output)
- Addition Plus Alteration of Existing Building
- Alteration of Existing Building

These input options are required even though the ACM may not have the capability of performing any existing building analysis. Any ACM without the capability of analyzing existing building alterations with or without an addition must inform the user that the ACM cannot analyze alterations in existing buildings and that the ACM must go into a noncompliance mode when the user selects a type of project it is incapable of analyzing. This precludes any compliance output for such cases. Special calculation and reporting for ACMs with automated analysis of additions and alterations are required and are covered in Section 3.1--Optional Compliance Capabilities-- and Section 2.7--Required Standard Reports**.**

2.1.2 Scope of Compliance Submittal

For each building or separately permitted space, ACMs must also require the user to identify the scope of the compliance submittal from the following list:

- Envelope only
- Mechanical only
- Envelope and Lighting
- Envelope and Mechanical
- Lighting and Mechanical
- Envelope, Lighting and Mechanical

Each of these situations requires specific assumptions, input procedures and reporting requirements. These requirements are documented in either Chapter 2--Required Loads Capabilities and Required Systems and Plant Capabilities-- and Chapter 4--Compliance Supplement. **ACMs must only produce reports specific to the scope of the submittal determined for the run.** Hence an Envelope Only scope run is only allowed to produce ENV forms and PERF forms that are designated **Envelope Only** and the tabulated total number of pages printed on the output must be consistent with this limited output requirement.

The information about installed service water heating system(s) is included in the mechanical compliance submittal forms. ACMs must calculate the energy use for both the proposed system(s) and the reference system(s) [energy budget] and provide the results on the PERF forms. The energy budget is calculated in accordance with Section 2.5 (Service Water Heating--Required capabilities) of this manual. If the energy used by the proposed water heating system(s) is less than the energy budget, the credit may be traded off for other building features. Alternatively, for high-rise residential buildings, users may show service water heating compliance by meeting the prescriptive requirements of Section 151(f)(8~~9~~) of the standards. When the compliance for the service water heating is shown prescriptively, tradeoff between the service water heating and other building components is not allowed.

When a building has a mixed scope of compliance, such as a speculative building where all the envelope is being permitted but the core includes lighting as well as portions of the envelope, **two** (or more) compliance runs must be performed and forms from different runs must be submitted for the appropriate spaces. The scope of submittal for the building core compliance run will be **Envelope & Lighting** and the scope of submittal for the compliance run for the remainder of the building will be **Envelope Only**.

2.1.3 New Building or Addition Alone

ACMs are required to be able to perform compliance on new buildings and additions as if they were new (or newly conditioned), stand-alone, buildings. ACMs may do this by treating an addition alone as a new building, but an addition modeled in this way must be reported on all output forms as a **Stand Alone Addition.**

2.1.3.1 Partial Permit Applications

Description: ACMs must require the user to input the components of the building for which a permit is being requested. Building components are Envelope, Mechanical, and Lighting. In a partial permit application one or more of the following conditions may occur:

1. No envelope compliance (no envelope submittal)
2. No mechanical compliance (no mechanical submittal)
3. No lighting compliance (no lighting submittal)

Assumptions for each of these conditions for both the *standard* and *proposed design* are described below.

Note: A partial permit application involving no envelope compliance creates an exceptional condition. This requires either a copy of the previous envelope compliance approval or an equivalent demonstration by the applicant (to the satisfaction of the local enforcement agency) that the building is conditioned and an occupancy permit has previously been issued by the local enforcement agency.

The exceptional condition list must indicate the presence of an existing or previously-approved envelope documentation and form must be produced to document the existing envelope. No envelope (ENV) compliance forms may be output as part of the compliance output when the user selects this option.

Modeling Rules for Proposed Design:

No envelope compliance. The envelope shall be modeled according to the as-built drawings and specifications of the building or as it occurs in the previously-approved compliance documentation of the building. All envelope features and inputs required for ACMs by this manual must be entered.

No mechanical compliance. ACMs shall model default heating and cooling systems according to the rules in Section 2.4.2.26 (Modeling Default Heating and Cooling Systems). ACMs may not allow the entry of an HVAC system and must automatically model the default system. Economizer controls will be modeled as indicated in the Standard Design Assumptions for Air Economizers based on system total (sensible + latent) cooling capacity.

No lighting compliance. Previously-approved lighting plans with approved lighting compliance forms may be entered as Tailored Lighting at the approved lighting power levels shown in the construction and previously-approved compliance documents and installed as approved. The exceptional conditions list on the PERF-1 form must indicate that previously-approved lighting plans and compliance forms must be resubmitted with the application.

In the absence of approved lighting plans and lighting compliance forms, the ACM shall model the lighting system according to Section 2.3.2.1 (Lighting) using the rules for *Lighting compliance not performed.*

Modeling Rules for Reference Design (All):

No envelope compliance. The envelope shall be identical to the proposed design.

No mechanical compliance. The mechanical systems shall be identical to the proposed design.

No lighting compliance. With previously approved lighting plans, the lighting levels for each space shall be equal to the approved design. No lighting (LTG) compliance forms may be output with the compliance output. The local enforcement agency should verify that the lighting has already been approved and installed or, if recently designed and approved, should verify the independent lighting approval.

In the absence of approved lighting plans and lighting compliance forms, the ACM shall model the lighting system according to Section 2.3.2.1 (Lighting) using the rules for *Lighting compliance not performed.*

2.1.4 Climate Zone

The program must account for variations in energy use due to the effects of the sixteen (16) California weather/climate zones. Weather/Climate information for the compliance simulation is derived from one of sixteen (16) different data sets for the sixteen climate zones. These sixteen climate zone weather data sets are the official weather data for each zone and hourly data from other weather tapes may not be used for compliance purposes (see Section 2.6). However, the data from these tapes may be adjusted to local conditions by methods approved by the Commission or by the reference method (see Appendix C) that adjusts for local design temperature extremes . **The same weather data must be used for the standard and proposed designs.** The ACM must use climate data and accept input for latitude, longitude and elevation of the weather file which will be used by the reference program and method to determine compliance. The reference method uses a full 8760 hour year of hourly data. ACMs must either use the hourly data based on the CECREV2 ASCII data or summarized, sampled, or averaged data consistently derived from the CECREV2 ASCII hourly data files as long as the ACM passes the test criteria for all minimum tests.

2.1.5 Reference Year

The 1991 calendar year must be used as the basis for the frequency and timing of the occurrence of holidays, Saturdays and Sundays. The reference method observes the holidays listed in Section 2.3.3.3 of this manual. This is a fixed compliance input that must be the same for both the standard and proposed designs. The reference method uses CECREV2 hourly data in WYEC format for the sixteen climate zones. Weather data is available in DOE compressed format for the reference computer simulation program along with programs to produce weather data from these files customized to the design weather data for each city in California. The weather data is also available in archived ASCII format for all 8760 hours for each of the 16 climate zones.

Developers of ACM programs may request an electronic copy of the weather data and programs to customize the weather information for each city in California by writing to:

California Energy Commission
Energy Efficiency Division
Attention: Nonresidential ACM Manual
1516 Ninth Street, MS-26~~42~~
Sacramento, California 95814

2.1.6 Output Reports

Compliance output is highly restricted in quantity and format. All non-default inputs **must** be reflected directly in the output. This can also be accomplished by changes in directly-related output values and the forms reflecting those changes **must** be printed when any compliance output forms are selected. Exceptional user entries or values outside of "normal" ranges must be printed and must be clearly flagged in the output so that the plan checker and field checker can and will readily note these user entries or values. Exceptional user entries include such entries as process loads, tailored ventilation, and tailored lighting and modifications to certain default values specified herein. When the user enters such exceptional input in a compliance run, the ACM must automatically print the forms containing such user inputs and exceptional conditions must be indicated on the PERF-1 form as part of the special conditions verification checklist for the plan checker and field inspector. This verification list must **COMMAND THE ATTENTION** of anyone reviewing the output and must be included with all performance compliance submittals even if no exceptional conditions are reported. In particular exceptional inputs **must** be reflected on the relevant ENV, MECH, or LTG forms **and** the PERF-1 Form and the forms showing these exceptional entries **must** be printed when any compliance output forms are selected.

For a compliance documentation run, the ACM must automatically determine the forms to be printed and the total number of pages (T) required to print those forms and must print exactly that number of pages and all ACM-determined forms. This determination must be made based on the user's description of the scope of compliance, the building characteristics, and the user's selection of a compliance run. ACMs may not allow the user to select specific forms to be printed in a compliance run (as distinguished from a diagnostic run) where printed or disk compliance output is requested. Each page (N) of the required output must indicate Page N of T in the page header, the unique compliance runcode and the initiation time of the compliance run. The PERF-1 must list or indicate all of the forms required for a valid submittal, including those required to be done by hand.

Diagnostic information not directly related to compliance or required to be reported by this manual **shall not be printed or output in printer format** for a compliance documentation run. ACMs may have a separate type of diagnostic output for the user's use but it must be distinctly different from compliance output. Distinctly different means that diagnostic output could not be confused with compliance output by a plan checker. At a minimum, diagnostic output shall **not** use form headers or output formats similar to compliance forms.

2.1.7 Certification Testing

A specific set of compliance comparison tests to evaluate ACMs are described in Chapter 5. Using these tests, the difference between the reference method's compliance margins and an ACM's compliance margins will be subjected to specific test criteria. These test criteria must be met for every test. The test criteria are designed to minimize the possibility that an approved ACM will determine that a specific proposed building complies with California's building energy efficiency standards when the reference method would determine otherwise. The test criteria **specifically do not** prevent an ACM from being conservative with regard to compliance but requires the ACM to produce results similar to those of the Commission’s reference program. In addition to satisfying the test criteria, the ACM must conform to all of the input and output requirements described in this manual and some calculation procedural requirements that all ACMs must meet.

These tests simultaneously exercise various ACM analytical capabilities and various aspects of the custom budget process relative to the reference program and the official reference custom budget procedures. To qualify for approval for compliance use, an ACM must have compliance margins that meet specified acceptance criteria relative to the reference procedures' compliance margins for each and every specified test.

An ACM may use these procedures directly or they may use procedures that are similar to these procedures or procedures that approximate the reference method results with sufficient accuracy to meet the criteria described in Chapter 5 for the minimum capability tests. In particular, when this manual uses the term **ACMs must model** it means that ACMs must be able **to quantitatively approximate** the changes in energy use due to particular envelope, lighting, or HVAC features of a building in such a way that the ACM is capable of meeting all test criteria in Chapter 5 for each and every test. All ACM estimates for lighting and receptacle energy use must be within a few percent of the reference method results. ACMs, however, **must also be capable of accepting appropriate inputs and producing the required outputs subject to the limitations** described in this chapter and elsewhere in this manual to be approved for compliance purpose

2.2 Building Shell - Required Capabilities

All ACMs must receive inputs for each different opaque surface (wall, roof/ceiling, or floor) that separates the conditioned space from the unconditioned or semi-conditioned space or the ground, including each demising wall (which consequently includes each party wall.) These inputs include construction framing type, orientation and tilt, location and area for each exterior surface. An ACM must also allow the user to enter inputs to determine heat transfer and heat capacity characteristics of exterior opaque surfaces for the proposed design. The heat capacity of standard design exterior surface is identical to the heat capacity of the proposed design exterior surface. Based on this heat capacity, the standards specify a required ~~U-value~~U-factor for the exterior surface that is used as the heat transfer characteristic for the standard design exterior surface.

For all exterior surfaces/assemblies it is assumed that the ~~U-value~~U-factors listed in the building standards include an exterior air film R-value of 0.17 h-ft^2-^{o}F/Btu, which the reference method strips off and replaces with a simulated outside air film resistance. Azimuthal orientation and tilts of surfaces must be entered to the nearest degree.

Standard design requirements are labeled as applicable to one of the following options:

- Existing Unchanged
- Altered Existing
- New
- All

with the default condition for these four specified conditions being “All”. An ACM without the optional capability of analyzing additions or alterations must classify and report all surfaces as “All”.

All ACMs must separately report information about demising walls, fenestration in demising walls, exterior walls, and fenestration in exterior walls. Demising walls and demising wall fenestration separate conditioned spaces from enclosed unconditioned or semi-conditioned spaces. Party walls are always considered to be demising walls when they separate spaces controlled or occupied by different tenants. For the purpose of compliance, the adjacent enclosed spaces not controlled by the tenant of the given space or by a single manager of the building are unconditioned. This assumption means that party walls are treated as demising walls and adjacent tenant spaces are modeled as enclosed unconditioned spaces. To avoid modeling adjacent spaces that are not part of the permit, for purposes of standards compliance, an ACM must assume that the demising wall is adiabatic and no heat transfer occurs through it. **In this manual, the word “unconditioned” is used to refer to both unconditioned and semi-conditioned spaces**.

2.2.1 Construction Assemblies

2.2.1.1 Construction Identifiers

Description: A unique alphanumeric identifier describing each construction type. Separate identifiers must be used to refer to proposed and standard designs of the same construction type.

2.2.1.2 Heat Capacity

Description: The ability of a construction assembly to absorb thermal energy. The heat capacity, HC, of an assembly is calculated by using the following equation:

$$HC = \sum_{i=1}^{n} (r_i \times c_i \times t_i)$$

where:

n is the total number of layers in the assembly
r_i is the density of the i^{th} layer
c_i is the specific heat of the i^{th} layer
t_i is the thickness of the i^{th} layer

all in consistent units.

For framed assemblies where the insulation layer also includes framing members, ACMs must calculate the heat capacity of the framing/insulation layer based on weighted average density and specific heat of the framing and insulation.

DOE Keyword: DENSITY
SPECIFIC-HEAT
THICKNESS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM shall calculate the overall *heat capacity* of a construction assembly according to the above formula using the layers as they occur in the construction documents. Alternatively, ACMs may require an explicit input for the assembly's overall *heat capacity*.

User Input: Yes, or may be calculated by the program according to the above formula.

Low Caution: ACMs must output a warning note on the ENV-1 form if the user specified or calculated overall HC is less than 0.6 Btu/ft^2-^{o}F.

Modeling Rules for Reference Design (All): ACMs shall determine standard design assemblies from the overall *heat capacity* of the proposed construction assembly. The heat capacity of the reference construction assembly shall be the same as the heat capacity of the proposed assembly.

2.2.1.3 Construction Types

Description: Exterior walls have the following five construction types: (1) wood framing; (2) steel framing; (3) medium-mass masonry with 7.0≤HC<15.0 Btu/ft^2-^{o}F; (4) heavy-mass masonry with HC≥15.0 Btu/ft^2-^{o}F; (5) other; and (6) composite. Exterior floors and soffits have the following two construction types: (1) light-mass with HC<7.0 Btu/ft^2-^{o}F; and (2) medium or heavy-mass with HC≥7.0 Btu/ft^2-^{o}F. All exterior roofs and ceilings are of the same type.

2.2.1.4 Absorptance

Description: The fraction of the incident solar radiation absorbed as heat on the construction assembly's opaque exterior surface.

DOE Keyword: ABSORPTANCE

Input Type: Default

Tradeoffs: ~~Neutral~~Yes

Modeling Rules for Proposed Design: ~~The ACM must either receive use user input for the absorptance of each opaque exterior surface or use the default value.~~
For roofs, qualifying cool roofs shall model an absorptance of 0.45. All other roofs shall use the default value.
For other opaque surfaces, the ACM must either receive user input for the absorptance of each opaque exterior surface or use the default value.
~~value.~~

Cool Roof Value: Roof = 0.45

To qualify as a cool roof the roof must meet the requirements of Section 118 of the Standard, which states:

(a) Effective January 1, 2003, a roof shall be considered a cool roof if the roof is certified and labeled according to requirements of Section 10-113 and if the roof meets conditions (1) or (2) below. Prior to January 1, 2003, manufacturer's published performance data shall be acceptable to show compliance with one of the following conditions.

(1) Roof of concrete tile (per ASTM C55-99) and clay tile (per ASTM C1167-96) require a minimum initial total solar reflectance of 0.40 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

(2) All other roofs require a minimum initial total solar reflectance of 0.70 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

(3) Liquid applied roofing products shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements of ASTM D6083-97 when tested in accordance with ASTM D6083 97 for the following key properties:
** Initial Tensile Strength*
** Initial Elongation*
** Elongation After 1000 Hours Accelerated Weathering*
** Permeance*
** Accelerated Weathering*

Default: Roof = 0.70
Exterior wall = 0.70

Demising wall = 0.05

Low Value: Exterior wall = 0.20
Demising wall = 0.02

High Value: Exterior wall = 0.90
Demising wall = 0.80

Cool Roof Caution Warning on PERF-1 if a cool roof credit is claimed.

Low Caution: Warning on PERF-1 that the absorptance of an exterior wall is less than 0.50

Modeling Rules for Reference Design (All): ~~For the reference method, the absorptance of each opaque exterior surface is the same as the proposed design.~~
For the reference method, the roof absorptance shall be modeled at 0.70. The absorptance of each other opaque exterior surface is the same as the proposed design.

2.2.1.5 Surface Emissivity

Description: The ratio of radiation intensity from the construction assembly's opaque exterior surface to the radiation intensity at the same wavelength from a blackbody at the same temperature.

DOE Keyword: OUTSIDE-EMISS

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall model a surface emissivity of 0.90.

Modeling Rules for Reference Design (All): The surface emissivity of the reference design shall be the same as the surface emissivity of the proposed design.

2.2.1.6 Wood Frame

Description: A construction assembly that consists of wood framing members, insulation or air in the cavity between the framing members with exterior and interior finish.

DOE Keyword: EXTERIOR-WALL
LAYERS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Wood-framed assemblies consist of a framing section and a cavity section. ACMs shall calculate the overall R-value of the assembly using ASHRAE Parallel Path method and the following framing percentages:

> *Walls: F*raming percentages for frame spacing of 16” O.C., 24” O.C., and 48” O.C. are 15%, 12%, and 8% respectively.
>
> *Floors/soffits and roofs/ceilings:* The framing percentage for frame spacing of 16” O.C. and 24” O.C. are 10% and 7% respectively.

Using the above calculated overall R-value, ACMs shall determine the equivalent cavity insulation/framing R-value that would result in the same overall R-value for the assembly when all assembly layers including the insulation/framing layer are added as a series of homogeneous layers. The heat capacity of the cavity insulation/framing shall be the volume weighted average of the cavity insulation and the framing.

Modeling Rules for Reference Design (New & Altered Existing): The standard design wall and floor/soffit assemblies are dependent on the HC of the proposed assembly. For wall, floor/soffit, and roof/ceiling assemblies, an ACM must require the user to enter values needed to determine heat capacity, HC, for the proposed design and use it to determine the standard design ~~U-value~~U-factor.

ACMs must model standard design wall assemblies using the same **wood frame construction,** layers, and modeling technique as the proposed wall assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the Standards for wood-framed walls and the applicable climate zone.

ACMs must model standard design floor/soffit assemblies using the same **wood frame construction,** layers, and modeling technique as the proposed floor/soffit assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the Standards for “other” and the applicable climate zone.

ACMs must model standard design roof/ceiling assemblies using the same **wood frame construction,** layers, and modeling technique as the proposed roof/ceiling assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the standards and the applicable climate zone.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall model each existing wood-framed assembly as they occur in the existing building using the same procedure as described above.

2.2.1.7 Steel Frame

Description: A construction assembly that consists of steel framing members, insulation or air in the cavity between the framing members with interior and exterior finish.

DOE Keyword: EXTERIOR-WALL
LAYERS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Steel-framed assemblies consist of a framing section and a cavity section. ACMs shall calculate the overall R-value of the assembly using ASHRAE Zone Method and the following framing percentages:

> *Walls: F*raming percentages for frame spacing of 16" O.C., 24" O.C., and 48" O.C. are 15%, 12%, and 8% respectively.
>
> *Floors/soffits and roofs/ceilings:* The framing percentage for frame spacing of 16" O.C. and 24" O.C. are 10% and 7% respectively.

The calculated overall R-value of the assembly shall be within 10 percent of the overall R-value calculated by the EZFRAME program.

Using the above calculated overall R-value, ACMs shall determine the equivalent cavity insulation/framing R-value that would result in the same overall R-value for the assembly when all assembly layers including the insulation/framing layer are added as a series of homogeneous layers. The heat capacity of the cavity insulation/framing shall be the volume weighted average of the cavity insulation and the framing.

Modeling Rules for Reference Design (New & Altered Existing): The standard design wall and floor/soffit assemblies are dependent on the HC of the proposed assembly. For wall, floor/soffit, and roof/ceiling assemblies, an ACM must require the user to enter values needed to determine heat capacity, HC, for the proposed design and use that same value of heat capacity for the standard design.

ACMs must model standard design wall assemblies using the same **steel frame construction,** layers, and modeling technique as the proposed wall assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the Standards for steel-framed walls and the applicable climate zone.

ACMs must model standard design floor/soffit assemblies using the same **steel frame construction,** layers, and modeling technique as the proposed floor/soffit assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the Standards for "other" and the applicable climate zone.

ACMs must model standard design roof/ceiling assemblies using the same **steel frame construction,** layers, and modeling technique as the proposed roof/ceiling assembly. An ACM shall adjust the cavity insulation in order for the overall ~~U-value~~U-factor of the standard assembly to match the ~~U-value~~U-factor requirement listed in Table 1-H or 1-I of the standards and the applicable climate zone.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall model each existing steel-framed assembly as they occur in the existing building using the same procedure as described above.

2.2.1.8 Masonry

Description: A construction assembly that consists of masonry materials such as poured concrete, solid brick, fully grouted masonry units, or perlite filled hollow concrete masonry blocks.

DOE Keyword: EXTERIOR-WALL
LAYERS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall model masonry assemblies as a single construction using ASHRAE Table 4 in ASHRAE Handbook, 1997, Fundamentals Volume, Chapter 24.

Modeling Rules for Reference Design (New & Altered Existing): The standard design wall and floor/soffit assemblies are dependent on the HC of the proposed assembly. For wall, floor/soffit, and roof/ceiling assemblies, an ACM must require the user to enter values needed to determine heat capacity, HC, for the proposed design and use that same value of heat capacity for the standard design.

ACMs must determine the standard design wall assemblies using homogeneous **masonry** material with a ~~U-value~~U-factor matching the requirement listed in Table 1-H or 1-I of the Standards for the applicable HC range and the climate zone.

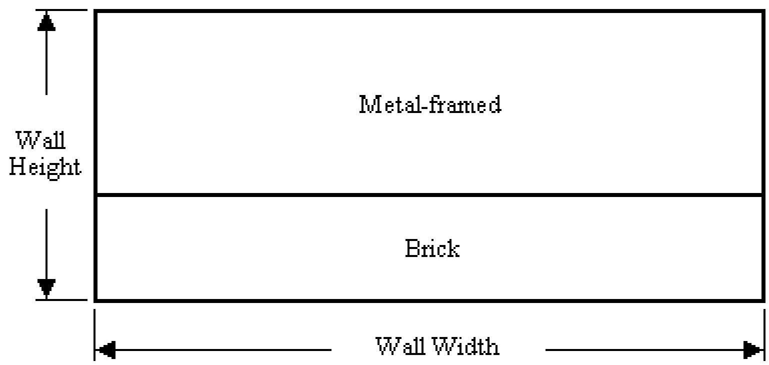
ACMs must determine the standard design raised floor/soffit assemblies using homogeneous **masonry** material with a ~~U-value~~U-factor matching the requirement listed in Table 1-H or 1-I of the Standards for HC ≥ 7.0 and the applicable climate zone. For high-rise residential buildings and guest rooms of hotel/motel buildings **ACMs must adjust the listed ~~U-value~~U-factor for raised floor/soffit assemblies for climate zones that require insulation as indicated in Table 1-I**.

ACMs must determine the standard design roof/ceiling assemblies using homogeneous **masonry** material with a ~~U-value~~U-factor matching the requirement listed in Table 1-H or 1-I of the Standards and the applicable climate zone.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall model each existing masonry assembly as they occur in the existing building using the same procedure as described above.

2.2.1.9 Composite Walls

Description: Exterior wall assemblies that consist of any combination of wood framing, steel framing, masonry, and other types of wall construction assemblies. An example of a composite wall made up of a masonry section and a steel-framed section is shown below:



DOE Keyword: EXTERIOR-WALL
LAYERS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall model each type of construction in a composite wall shown in the construction documents as described above.

Modeling Rules for Reference Design (New & Altered Existing): For each construction type of the composite wall ACMs shall use the applicable technique to model the standard design. The ~~U-value~~U-factor of each type must match the applicable requirements of Table 1-H or 1-I of the Standards for the applicable HC range and the climate zone.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall model each existing composite wall as it occurs in the existing building using the procedure described above.

2.2.2 Above-Grade Envelope

2.2.2.1 Exterior Partitions

Description: Above-grade exterior partitions that separate conditioned spaces from the ambient air, unconditioned attic spaces and crawl spaces, courtyards, or unconditioned spaces that are not enclosed. Exterior walls, raised floors, roofs, and ceilings are exterior partitions.

The area of exterior partitions is defined by specifying the width of the partition and a height equal to the total height of the floor.

DOE Keyword: HEIGHT, WIDTH

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: For each exterior partition of each floor, ACMs shall receive inputs for the height and width as they occur in the construction documents.

Modeling Rules for Reference Design (All): The standard design shall model each exterior partition with the same height and width as the proposed design.

2.2.2.2 Surface Azimuth of Exterior Partitions

Description: The direction of an outward normal projecting from the partition's exterior surface relative to the true north. Positive azimuth is measured clockwise from the true north.

DOE Keyword: AZIMUTH

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: Azimuth of each exterior partition shall be input as shown in the construction documents for the building to the nearest whole degree.

Modeling Rules for Reference Design (All): The azimuth of each exterior partition shall be modeled in the same manner as it occurs and is modeled in the proposed design.

2.2.2.3 Surface Tilt of Exterior Partitions

Description: Inclination of a partition's exterior surface from horizontal.

DOE Keyword: TILT

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The tilt of each exterior surface shall be input as shown in the construction documents for the building to the nearest whole degree.

Modeling Rules for Reference Design (All): The tilt of each exterior surface shall be modeled in the same manner as it occurs and is modeled in the proposed design.

2.2.2.4 Construction of Exterior Partitions

Description: The construction assembly describing the exterior partition. The modeling rules are described in Section 2.2.1--Construction Assemblies.

2.2.2.5 Demising Partitions

Description: A barrier that separates a conditioned space from an enclosed unconditioned space. "Party walls" separating tenants, a partition separating a conditioned space from an unconditioned warehouse, and a glass partition separating a conditioned space from an unconditioned sunspace are examples of demising partitions.

DOE Keyword: INTERIOR-WALL
HEIGHT
WIDTH
NEXT-TO

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference design shall model demising partitions as adiabatic interior partitions. No heat transfer shall occur between the two adjacent spaces.

ACMs must require the user to input information for each demising partition including orientation and tilt, location, size, shape and construction as they occur in the construction documents. Window Management shall not be modeled for fenestration products separating conditioned and enclosed unconditioned spaces.

ACMs shall indicate in the compliance forms that demising partitions are used to separate the conditioned space from the unconditioned space. For framed demising partitions in a new construction, the compliance forms shall also indicate that R-11 insulation must be installed.

Modeling Rules for Reference Design (All): The standard design shall model each demising partition with the same thermal characteristics, orientation and tilt, location, size, shape and construction as the proposed design.

2.2.2.6 Interzone Walls

Description: The reference method shall model heat transfer through interior walls separating directly conditioned zones from other directly and indirectly conditioned zones as air walls. The reference program accounts for the thermal mass of interior walls as described in Section 2.2.2.13.

DOE Keyword: INTERIOR-WALL
WIDTH
HEIGHT
NEXT-TO

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall receive inputs for the width and height (or area) of all interzone walls as they occur in the construction documents. The reference program shall model interzone walls as air walls with zero (0) heat capacity and an overall ~~U-value~~U-factor of 1.0 Btu/h-ft^2-^{o}F.

Modeling Rules for Reference Design (All): The reference method models all interzone walls as they occur (and as they are modeled) in the proposed design.

2.2.2.7 Interior Floors

Description: The reference method shall model heat transfer through interior floors separating directly conditioned zones from other directly and indirectly conditioned zones.

DOE Keyword: INTERIOR-WALL
WIDTH
HEIGHT
NEXT-TO

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall receive inputs for the all interior floors as they occur in the construction documents.

Modeling Rules for Reference Design (All): The reference method models all interior as they occur (and as they are modeled) in the proposed design.

2.2.2.8 Return Air Plenums

Description: Return air plenums are considered conditioned spaces and must be modeled as part of the adjacent conditioned space.

2.2.2.9 Indirectly Conditioned Spaces

Description: ACMs shall allow users to explicitly model all indirectly conditioned spaces. All Minimum Loads Capabilities found in this manual apply to indirectly conditioned spaces. When indirectly conditioned spaces are explicitly modeled, **ACMs must require the user to identifying each zone as either directly or indirectly conditioned.**

At the user's choice, ACMs may model indirectly conditioned spaces as part of the directly conditioned space provided that the total volume and area of indirectly conditioned spaces included are each less than 15% of the total volume and less than 15% of the total conditioned floor area of the total indirectly and directly conditioned volume and floor area. (Refer to Chapter 4 for requirements applying to indirectly conditioned spaces included as directly conditioned spaces.) For the purposes of this manual, indirectly conditioned spaces can either be occupied or unoccupied. Descriptions of each of these space types are provided in Chapter 4. The requirements for each of these three cases are documented below.

2.2.2.9.1 Indirectly Conditioned Spaces Included in Directly Conditioned Space

Description: The requirements for modeling indirectly conditioned spaces when they are included in directly conditioned space are as described below.

DOE Keyword: SPACE
AREA
VOLUME
MULTIPLIER

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: Any indirectly conditioned space modeled as part of directly conditioned space shall be input as it occurs in the construction documents, including envelope, occupancy characteristics and lighting levels. Additionally, ACMs must assume mechanical heating and cooling is provided to the space, using the same system as the actual directly conditioned space.

Modeling Rules for Reference Design (All): ACMs must use the same configuration and occupancy characteristics for indirectly conditioned spaces modeled as directly conditioned space as the proposed design. Standard design assumptions for envelope performance, occupancy characteristics, lighting levels, and HVAC system assumptions shall be determined as if the space were directly conditioned.

2.2.2.9.2 Indirectly Conditioned Spaces that can be Occupied and Explicitly Modeled

Description: The requirements for modeling indirectly conditioned spaces that can be occupied and explicitly modeled are as described below.

DOE Keyword: SPACE
AREA
VOLUME
MULTIPLIER

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: For the proposed design ACMs shall receive input for indirectly conditioned spaces for area, configuration, and envelope as each space occurs in the construction documents. All internal loads, receptacle, occupant, process loads shall be determined identically to directly conditioned space.

The reference method will treat the space as a conditioned zone [ZONE-TYPE = CONDITIONED] with heating and cooling off [HEATING-SCHEDULE & COOLING-SCHEDULE set to off] and fans on so that mechanical ventilation will be modeled according to Table 2-1 or 2-2.

Modeling Rules for Reference Design (All): ACMs must use the same configuration and modeling assumptions for indirectly conditioned spaces that can be occupied as the proposed design. Standard design assumptions for envelope performance shall be determined as if the space were directly conditioned.

The reference method will not model mechanical heating or cooling for these spaces, however mechanical ventilation (CFM/sf) will be modeled according to Table 2-1 or 2-2. Lighting levels shall be established identical to directly conditioned space standard design.

2.2.2.9.3 Indirectly Conditioned Spaces that cannot be Occupied and Explicitly Modeled

Description: The requirements for modeling indirectly conditioned spaces that cannot be occupied and explicitly modeled are as described below.

DOE Keyword: SPACE
AREA
VOLUME
MULTIPLIER

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: For the proposed design, all ACMs shall receive input for indirectly conditioned spaces for area, configuration, and envelope as each space occurs in the construction documents. All internal loads, ventilation, receptacle, lighting, occupant and process loads shall be zero.

No mechanical heating, cooling or ventilation shall be modeled for indirectly conditioned spaces that cannot be occupied. As in the standard design, for these spaces the reference method models lightweight mass by using a light furniture category of 30 pounds per square foot in DOE 2.1 to generate the lightweight standard weighting factors for these spaces. This lightweight mass is meant to approximate the materials found in conditioned spaces that cannot be occupied.

Modeling Rules for Reference Design (All): ACMs must use the same configuration and modeling assumptions for indirectly conditioned spaces that cannot be occupied as the proposed design. Standard design assumptions for envelope performance shall be determined as if the space were directly conditioned.

For these spaces the reference method models lightweight mass by using a light furniture category of 30 pounds per square foot in DOE 2.1 to generate the lightweight standard weighting factors for these spaces. This lightweight mass is meant to approximate the materials found in indirectly conditioned spaces that cannot be occupied.

The reference method will not model mechanical heating, cooling or ventilation for indirectly conditioned spaces that cannot be occupied.

2.2.2.10 Enclosed Unconditioned and Semi-Conditioned Spaces

Description: ACMs shall require the user to explicitly model any enclosed unconditioned and semi-conditioned spaces such as stairways, warehouses, unoccupied adjacent tenant spaces, attached sunspaces, attics and crawl spaces *if and only if* they are part of the permitted space. ACMs must require the user to identify the space as **unconditioned** and to enter all applicable envelope information, in a similar manner to a conditioned space. **In this manual, the word "unconditioned" is used to refer to both unconditioned and semi-conditioned spaces.**

If the enclosed unconditioned space is not a part of the permitted space, ACMs *may* allow the user to either explicitly model the space or ignore it by modeling the partition separating the condition space from the enclosed unconditioned space as an adiabatic demising partition (see Section 2.2.2.5).

DOE Keyword: SPACE
AREA
VOLUME
MULTIPLIER

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: If enclosed unconditioned spaces are explicitly modeled, ACMs shall model the envelope characteristics of the unconditioned spaces as input by the user, according to the plans and specifications for the building.

All internal gains and operational loads (occupants, water heating, receptacle, lighting and process loads, ventilation) in unconditioned spaces shall be equal to zero. Infiltration shall be equal to 0.038 times the total wall area exposed to ambient outdoor air.

If enclosed unconditioned spaces are not modeled, the reference program shall model the partitions separating condition spaces from enclosed unconditioned spaces as adiabatic demising partitions.

Modeling Rules for Reference Design (All): ACMs shall model unconditioned spaces exactly the same as the proposed design.

2.2.2.11 Concrete Slab Floors on Grade

Description: Slab-on-grade floor construction typically consisting of 3-1/2 inch thick poured concrete on grade.

DOE Keyword: UNDERGROUND-FLOOR
WIDTH
HEIGHT
MULTIPLIER

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference method shall model concrete slab floors on grade with a construction consisting of concrete whose thickness must be input by the user and one foot of earth. ACMs shall model an effective ~~U-value~~U-factor of (0) for slab-on-grade floors.

The reference method assumes soil layers to have a thermal conductivity of 0.50 Btu-ft/h-ft^2-^{o}F and a density of 85 lb/ft^3. Concrete is assumed to have a thermal conductivity of 0.7576 Btu-ft/h-ft^2-^{o}F and a density of 140 lb/ft^3. The reference method assumes that both soil and concrete have a specific heat of 0.20 Btu/lb-^{o}F.

Modeling Rules for Reference Design (All): ACMs shall use the same slab floor constructions and areas as the proposed design.

2.2.2.12 Exterior Doors

Description: Doors in exterior partitions.

DOE Keyword: DOOR
WIDTH
HEIGHT
SETBACK
MULTIPLIER

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall receive inputs for each exterior door, including construction, thermal characteristics, orientation and tilt, location and area for all doors as they occur in the construction documents.

Modeling Rules for Reference Design (All): The reference method shall model the standard design with the same constructions, orientation and tilt, locations and areas as the proposed design.

2.2.2.13 Light Mass

Description: The heat capacity of interior walls and furniture are modeled as lightweight mass.

DOE Keyword: FURNITURE-TYPE
FURN-WEIGHT
FURN-FRACTION

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall model lightweight mass with constructions specified below. **ACMs shall not have direct user inputs for interior light weight mass.** The reference method determines lightweight mass exclusively as a function of floor area using DOE-2 furniture inputs as described below.

The reference method assumes that lightweight mass is determined from the floor area of the modeled spaces. In the reference method, lightweight mass is modeled through the use of the DOE 2.1 furniture inputs. For directly conditioned spaces and indirectly conditioned spaces that can be occupied the internal mass category is deemed to be [FURNITURE-TYPE = HEAVY]; the average weight of the light mass (furniture and equipment) is assumed to be 80 pounds per square foot [FURN-WEIGHT = 80]; and 85% of the floor is covered by lightweight (furniture) mass [FURN-FRACTION = 0.85]. This furniture fraction determines the fraction of solar gains going to the furniture/light mass. Thus the reference method assigns 85% of the total solar heat gain normally falling on the floor to the furniture instead.

For indirectly conditioned spaces that cannot be occupied the internal mass category is deemed to be [FURNITURE-TYPE = LIGHT]; the average weight of the light mass (furniture and equipment) is assumed to be 30 pounds per square foot [FURN-WEIGHT = 30]; and 85% of the floor is covered by lightweight (furniture) mass [FURN-FRACTION = 0.85].

Modeling Rules for Reference Design (All): The standard design shall model the same lightweight mass as the proposed design.

2.2.2.14 Fenestration products

Description: Any transparent or translucent material plus any sash, frame, mullions, and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, French doors, skylights, curtain walls, and garden windows.

Windows include not only common windows but also all fenestration products in the walls of the building envelope. Examples of such fenestration products include all windows and glazing materials, glass block walls, translucent panels, and glass doors. Walls are portions of the building envelope with tilts from vertical to less than 30 degrees from vertical.

DOE Keyword: WINDOW

Input Type: Required

2.2.2.14.1 Fenestration Orientation and Tilt

Description: The reference method models the actual azimuth (direction) and surface tilt of windows and skylights (fenestration products) in each wall and roof surface.

DOE Keyword: Same as EXTERIOR-WALL

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: Azimuth and surface tilt of each glazing surface shall be input as they occur in the construction documents.

Modeling Rules for Reference Design (All): Azimuth and surface tilt of each glazing surface shall be the same as they occur in the proposed design.

2.2.2.14.2 Fenestration Thermal Properties

Description: ACMs shall model the overall ~~U-value~~U-factor and Solar Heat Gain Coefficient (SHGC) for each fenestration assembly, including inside and outside air films and effects of framing, spacers and other non-glass materials as applied to the full rough-out fenestration area. For manufactured fenestration assemblies, the overall ~~U-value~~U-factor and SHGC are from the NFRC label attached to the assembly or from default values listed in Tables 1-D and 1-E of the Standards.

For ~~each~~ site assembled vertical glazing ~~field-fabricated fenestration assembly~~ ~~assemblies~~ in buildings with 100,000 square feet of conditioned floor area or greater and 10,000 square feet of vertical glazing or greater, ACMs must allow the user to *either* input the default U~~-value~~ factor and SHGC listed in Tables 1-D and 1-E or use NFRC U-factor ratings for site built fenestration~~field-fabricated systems~~. For buildings under 100,000 square feet of conditioned floor area or with less than 10,000 square feet of vertical glazing, the user can either use NFRC ratings for site built fenestration ~~of the Standards~~ , default values from Tables 1-D and 1-E, *or* determine the U-factor from default values in Appendix I and calculate the assembly's ~~U-value and~~ SHGC using ~~a~~ the method shown in Appendix I~~approved by the Commission~~. For skylights that do not have U-factor and SHGC values certified to NFRC, the values shall be determined from Appendix I.

In this Section the word "Window" is used to refer to fenestration. A horizontal window with a tilt of up to 60 degrees from the horizontal is a skylight.

DOE Keyword: FRAME-CONDUCTANCE
FRAME-WIDTH
FRAME-ABS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: For manufactured windows, ACMs must require the user to input the ~~U-value~~U-factor and SHGC for each window from the NFRC label as it occurs in the construction documents for the building.

For site assembled vertical glazing ~~field-fabricated windows~~ in buildings with 100,000 square feet of conditioned floor area or greater and 10,000 square feet of vertical glazing or greater, ACMs must either use the default U-~~value~~ factor and SHGC listed in Tables 1-D and 1-E of the Standards *or* ~~calculate the overall U-value and SHGC using a method approved by the Commission.~~use NFRC ratings for ~~field fabricated systems~~ site built fenestration.

For site assembled vertical glazing ~~field-fabricated windows~~in buildings under 100,000 square feet of conditioned floor area or with less than 10,000 square feet of vertical glazing, ACMs must determine the U-factor and SHGC using procedures and defaults specified in Appendix I, or use NFRC ratings for site built fenestration~~field fabricated systems; or calculate the overall U-value and SHGC using a method approved by the Commission.~~

For skylights, ACMs must determine the U-factor and SHGC using procedures and defaults specified in Appendix I, or use NFRC ratings for ~~field fabricated systems~~ site built fenestration~~; or calculate the overall U-value and SHGC using a method approved by the Commission.~~ The reference program uses a FRAME ABSORPTANCE of 0.70.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall use the appropriate "Maximum ~~U-value~~U-factor " and RSHG or SHGC for the window as appropriate from Tables 1-H and 1-I of the Standards including the framing according to the occupancy type and the climate zone. The reference design uses a FRAME ABSORPTANCE of 0.70.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the existing design's ~~U-value~~U-factor and SHGC or RSHG as appropriate including the framing. The reference design uses a FRAME ABSORPTANCE of 0.70.

2.2.2.14.3 Area of Fenestration in Walls & Doors

Description: Fenestration surfaces include all glazing in walls and vertical doors of the building. The following inputs must be received.

Fenestration dimensions. For each glazing surface, all ACMs must receive an input for the glazing width and height. The glazing dimensions are those of the rough-out opening for the window(s) or fenestration product. The area of the fenestration product will be the width times the height. For fenestration products with glazing surfaces on more than a single side such as garden windows, the ACM must be able to accept entry for the dimensions of each side (glazing plus frame) with conditioned space on one side and unconditioned space on the other.

Display Perimeter. In a secondary menu (subordinate to the menu for fenestration area entries), the ACM must allow the user to specify a value for the length of display perimeter, in feet, for each floor or story of the building. **The user entry for Display Perimeter must have a default value of (0) zero. Note: Any non-zero input for Display Perimeter is an exceptional condition that must be reported on the PERF-1 exceptional condition list and must be reported on the ENV forms.** The value for Display Perimeter is used as an alternate means of establishing Maximum Wall Fenestration Area in the standard design (Title 24, § 143). As defined in Section 101(b) of the Standards, display perimeter is:

... the length of an exterior wall in a B-2 occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.

Floor Number. The ACM must also allow the user to specify the Display Perimeter associated with each floor (story) of the building.

DOE Keyword: WIDTH
HEIGHT

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall receive inputs for the proposed design fenestration width and height as they are documented on the construction documents.

Modeling Rules for Reference Design (New & Altered Existing): The reference method calculates the maximum allowed fenestration area. This *Maximum Wall Fenestration Area* is 40% of the gross exterior wall area of the building that is conditioned when display perimeter is not specified.

If Display Perimeter is specified, the *Maximum Wall Fenestration Area* is either 40% of the gross exterior wall area of the building, or six feet times the Display Perimeter for the building, whichever value is greater.

The reference method automatically calculates these two maximum fenestration areas for fenestration in walls and uses the greater of the two for the total glazing area of the reference building.

1. When the Window Wall Ratio in the proposed design is ≤ 0.40 or $\leq$ display perimeter $\times$ 6 feet, the standard design shall use the same wall fenestration height and width for each glazing surface of the proposed design exterior wall.

2. When the proposed design area of fenestration in walls and doors is greater than the maximum wall fenestration area described above, ACMs shall adjust the height and width of each glazing surface by multiplying them by a fraction equal to the square root of :

Maximum Allowed Wall Fenestration Area/Total Proposed Fenestration Area.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same fenestration area as the existing design.

2.2.2.14.4 Window-to-Wall Ratio

Description: Ratio of the total window area to the gross exterior wall area.

DOE Keyword: N/A

Input Type: Calculated based on the dimensions of exterior walls and windows.

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall calculate the window-to-wall ratio based on inputs for width and height of exterior walls and windows as they occur in the construction documents.

Modeling Rules for Reference Design (New & Altered Existing): For the standard design the area of each exterior wall construction shall equal the area of each exterior wall of the proposed design, except when the wall area of the proposed design exceeds the maximum allowable window-to-wall ratio (WWR). There are three cases, when the proposed design glazing exceeds the maximum allowable window-to-wall ratio (WWR), which must be accounted for:

(1) *One Wall Construction*. If the window occurs in a portion of wall where it abuts only one construction, the ACM must decrease the glazing area to the allowable maximum and increase the area of the wall accordingly.

(2) *Multiple Wall Constructions.* If the window occurs in a portion of wall where it abuts more than one construction in a given orientation, the ACM must increase the area of each adjacent wall construction by the same proportion, as glazing area decreases.

(3) *Propose WWR = 1.0*. If the Window-to-Wall Ratio, WWR, for any orientation or exterior surface is 1.0, the ACM must calculate the area weighted average (AWA) HC for all of the walls of the proposed design to determine an HC for the hypothetical wall. The glazing amount is reduced and a wall is inserted as follows:

> (a) AWA HC < 7.0 Btu/ft^2-^{o}F: The standard assembly is a steel-framed, lightweight wall with HC = AWA HC of the proposed walls and with a ~~U-value~~U-factor matching the requirement listed in Table 1-H or 1-I of the Standards for other walls with HC < 7.0 and the applicable climate zone.
>
> (b) AWA HC ≥7.0 Btu/ft^2-^{o}F: The standard assembly is a homogeneous material with a ~~U-value~~U-factor matching the applicable value listed in

Table 1-H or 1-I of the Standards for the applicable HC range and climate zone and the same HC as the proposed AWA HC.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same window-to-wall ratio as the existing design.

2.2.2.14.5 Solar Heat Gain Coefficient of Fenestration in Walls & Doors

Description: The reference method models the solar heat gain coefficient (SHGC) of glass including the framing, dividers, and mullions. The shading effects of dirt, dust, and degradation are purposely neglected and an ACM user may not adjust solar heat gain coefficients because of these effects. The ACM user's manual must reflect these restrictions on user entries.

If the user has specified Display Perimeter, ACMs may also receive an input in a subordinate menu for the Relative Solar Heat Gain (RSHG) requirement except for cases where local building codes prohibit or limit the use of overhangs or exterior shading devices. The use of this RSHG exception input is itself an exceptional condition that must be reported in the exceptional conditions checklist of the PERF-1 form.

DOE Keyword: SHADING-COEF

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Fenestration solar heat gain coefficient (SHGC) for each fenestration surface shall be input as it occurs in the construction documents for the building. ACMs that require inputting shading coefficient (SC) instead of SHGC shall calculate the fenestration’s shading coefficient using the following formula:

$$SC_{fenestration} = SHGC/0.87$$

Note: This equation is taken from Blueprint #57, dated Fall 1996. Since both SC for nonresidential buildings and SHGC apply to the entire rough-out opening, the adjustment for framing and divider has been removed.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall use the appropriate maximum RSHG values from Tables 1-H and 1-I of the Standards according to occupancy, climate zone, window wall ratio and orientation as the standard design solar heat gain coefficient. The maximum RSHG is different for north-oriented glass; for the purposes of establishing standard design solar heat gain coefficient, north glass is glass in walls facing from 45^{o} west (not inclusive) to 45^{o} east (inclusive) of true north.

If the user has claimed the RSHG exception for a section of display perimeter, the standard design uses the maximum RSHG for north glass found in Tables 1-H and 1-I of the Standards for any fenestration surface utilizing this exception.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same RSHG value as the existing design including the framing.

2.2.2.14.6 Area of Fenestration in Exterior Roofs

Description: ACMs must model the exposed surface area of fenestration in roofs separating those with transparent and translucent glazing. Such fenestration surfaces include all skylights or windows in the roofs including operable skylights and windows in the roofs of the building.

DOE Keyword: WIDTH
HEIGHT

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall receive inputs for width, length and height of each fenestration surface of the proposed design as they are shown in the construction documents.

Modeling Rules for Reference Design (New & Altered Existing): ACMs must calculate the maximum allowed area of fenestration in roofs. This *Maximum Roof Fenestration Area* is 5% of the gross exterior roof area of the entire permitted space or building.

1. When the Skylight Roof Ratio (SRR) in the proposed design is $\leq$ 0.05, for each roof fenestration, the standard design shall use the same dimensions as the proposed design.

2. When the Skylight Roof Ratio in the proposed design is > 0.05, the ACM shall adjust the dimensions of each roof fenestration of the standard design by multiplying them by a fraction equal to the square root of :

$$SRR_{standard}/SRR_{proposed}$$

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same fenestration area as the existing design.

2.2.2.14.7 Solar Heat Gain Coefficient of Fenestration in Roofs

Description: The reference method models the solar heat gain coefficient of the fenestration including the glass and framing. The shading effects of dirt, dust, and degradation are purposely neglected and an ACM user may not adjust solar heat gain coefficients because of these effects. The ACM user's manual must reflect these restrictions on user entries.

DOE Keyword: SHADING-COEF

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Fenestration solar heat gain coefficient for each fenestration surface in the roof(s) of a building or permitted space shall be input as it occurs in the construction documents for the building or permitted space. ACMs that require inputting shading coefficient (SC) instead of SHGC shall calculate the fenestration's shading coefficient using the following formula:

$$SC_{fenestration} = SHGC/0.87$$

Note: This equation is taken from Blueprint #57, dated Fall 1996. Since both SC for nonresidential buildings and SHGC apply to the entire rough-out opening, the adjustment for framing and divider has been removed.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall use the appropriate maximum solar heat gain coefficient from Tables 1-H and 1-I of the Standards according to the occupancy type, the climate zone and the fenestration type.

Modeling Rules for Reference Design (Existing Unchanged): The standard design shall use the same SHGC value as the existing design.

2.2.2.15 Overhangs

Description: ACMs must be capable of modeling overhangs over windows and must have the following inputs:

Overhang position. The distance from the edge of the window to the edge of the overhang.

Height above window. The distance from the top of the window to the overhang.

Overhang Width. The width of the overhang parallel to the plane of the window.

Overhang extension. The distance the overhang extends past the edge of the window jams.

Overhang Angle. The angle between the plane of window and the plane of the overhang.

DOE Keyword: OVERHANG-A
OVERHANG-B
OVERHANG-W
OVERHANG-D
OVERHANG-ANGLE

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: Overhangs shall be modeled in the proposed design for each window as they are shown in the construction documents.

Default: No overhang

Modeling Rules for Reference Design (New & Altered Existing): Overhangs shall not be modeled in the standard design; however, the fenestration must meet the prescriptive requirements for ~~U-value~~U-factor and solar heat gain coefficient.

Modeling Rules for Reference Design (Existing Unchanged): Overhangs shall be modeled in the same manner as they occur in the existing design.

2.2.2.16 Vertical Shading Fins

Description: ACMs must be capable of modeling vertical fins. Vertical fins shall affect the solar gain of fenestration products only. ACMs must have the following inputs:

Wall/window. Input must require the user to specify the wall/or window with which the fin is associated.

Horizontal position. The distance from the outside edge of the window to the fin.

Vertical position. The distance from the top edge of the fin to the top edge of the window.

Fin height. The vertical height of the fin.

Depth. The depth of the fin, measured perpendicularly from the wall to the outside edge of the fin.

DOE Keyword:

LEFT-FIN-A	RIGHT-FIN-A
LEFT-FIN-B	RIGHT-FIN-B
LEFT-FIN-H	RIGHT-FIN-H
LEFT-FIN-D	RIGHT-FIN-D

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: Vertical fins shall be modeled in the proposed design for each window as they are shown in the construction documents.

Default: No vertical fins

Modeling Rules for Reference Design (New Vertical fins shall not be modeled in the standard design; however, the fenestration must meet the prescriptive requirements for ~~U-value~~U-factor and

& Altered Existing): solar heat gain coefficient.

Modeling Rules for Reference Design (Existing Unchanged): Vertical fins shall be modeled in the same manner as they occur in the existing design.

2.2.2.17 Exterior Fenestration Shading Devices

Description: ACMs must be able to model exterior fenestration shading devices which affect the solar gain of glazing surfaces.

DOE Keyword: N/A

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: Exterior fenestration shading devices shall be modeled in the proposed design for each window as they are shown in the construction documents.

Note: Applications of Exterior Shading Devices are very limited; see Section 4.3.2.24 for restrictions on modeling Exterior Shading Devices.

Default: No exterior fenestration shading devices

Modeling Rules for Reference Design (New & Altered Existing): Exterior fenestration shading devices shall not be modeled in the standard design; however, the fenestration must meet the prescriptive requirements for ~~U-value~~U-factor and solar heat gain coefficient.

Modeling Rules for Reference Design (Existing Unchanged): Exterior fenestration shading devices shall be modeled in the same manner as they occur in the existing design.

2.2.2.18 Window Management

Description: The reference method simulates window management/interior shading devices in the following manner. ACMs may either use this method or a method yielding equivalent results.

Window solar heat gain coefficient is multiplied by a multiplier which gives the effective solar heat gain coefficient for combined shading device and window when the shading device covers the window.

DOE Keyword: SHADING-SCHEDULE

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall model fixed interior drapes with a solar heat gain coefficient multiplier of 0.80.

Modeling Rules for Reference Design (All): The standard design models the same window management as the proposed design.

2.2.3 Below-Grade Envelope

2.2.3.1 Underground Walls

Description: Underground walls separate a conditioned space from the adjacent soil or bedrock.

DOE Keyword: UNDERGROUND-WALL
WIDTH
HEIGHT

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference method shall model below grade walls using UNDERGROUND-WALL Keyword using their actual construction, input by the user, with an additional one-foot layer of earth coupled to the ground temperature. ACMs must set the effective ~~U-value~~U-factor of underground walls to zero

The reference method shall assume soil layers to have a thermal conductivity of 0.50 Btu-ft/h-ft^2-°F and a density of 85 lb/ft^3. Concrete is assumed to have a thermal conductivity of 0.7576 Btu-ft/h-ft^2-°F and a density of 140 lb/ft^3. The reference method assumes that both soil and concrete have a specific heat of 0.20 Btu/lb-°F.

Modeling Rules for Reference Design (All): ACMs shall model underground walls in the standard design exactly the same as they are modeled in the proposed design, including construction, area and position.

2.2.3.2 Underground Concrete Floors

Description: Underground concrete floors separate a conditioned space from the adjacent soil or bedrock.

DOE Keyword: UNDERGROUND-FLOOR
WIDTH
HEIGHT

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall model underground floor constructions and areas input as they occur in the construction documents along with a one-foot layer of soil beneath the floor. ACMs must set the effective ~~U-value~~U-factor of underground floors to zero.

The reference method shall assume soil layers to have a thermal conductivity of 0.50 Btu-ft/h-ft^2-^{o}F and a density of 85 lb/ft^3. Concrete is assumed to have a thermal conductivity of 0.7576 Btu-ft/h-ft^2-^{o}F and a density of 140 lb/ft^3. The reference method assumes that both soil and concrete have a specific heat of 0.20 Btu/lb-^{o}F.

Modeling Rules for Reference Design (All): The standard design shall use the same underground floor constructions, areas, and position as the proposed design.

2.3 Building Occupancy - Required Capabilities

The user of an ACM must be able to select an occupancy type from certain allowed tables. ACMs that do not have separate selection lists for ventilation occupancy assumptions and all other occupancy assumptions must allow the user to select from the occupancies listed in Table 2-1 and Table 2-2 or to select from an officially approved alternative sub-occupancy list that maps into those occupancies. ACMs that have separate occupancy selection lists for ventilation assumptions and other assumptions must use the occupancy selections given in tables in the building energy efficiency standards or approved alternative lists of occupancies. The occupancies listed in Table 1-F in the standards must be used for ventilation occupancy selections and the occupancies listed in Table 1-N in the standards must be used for selecting the remaining occupancy assumptions. Alternatively specific occupancy selection lists approved by the Commission that map into Tables 1-F or 1-N may be used.

A building consists of one or more occupancy types. ACMs cannot combine different occupancy types. Tables 2-1 and 2-2 describe all of the schedules and full load assumptions for occupants, lighting, infiltration, receptacle loads and ventilation. Full load assumptions are used for both the proposed design and the reference design compliance simulations.

2.3.1 Occupancy Assignment

2.3.1.1 Occupancy Types

Description: A modeled building must have at least one defined occupancy type. A default occupancy of "unknown" may be used to fulfill this requirement. Alternative Calculation Methods (ACMs) must model the following *occupancy* types for buildings and spaces when lighting compliance is not performed or lighting plans are submitted for the entire building. Occupancies that are considered as subcategories of these occupancies are listed below each occupancy. These occupancy types are also listed in Table 2-1 of this manual:

- Commercial and Industrial Work
  including both general and precision work, barber and beauty

shops, laundries, and dry cleaning

- Grocery Store
  including convenience stores
- Industrial and Commercial Storage
- Medical/Clinical
- Office
  including banks & financial institutions, courtrooms, accounting, art, design drafting and engineering spaces
- Other
  including corridors, restrooms, and support areas as well as ALL others not specifically mentioned herein for spaces without lighting plans
- Religious Worship, Auditorium, Convention Center
  including exhibit display areas and lobbies associated with religious worship spaces, auditoriums, and convention centers
- Restaurant
  including dining rooms, kitchens, hotel function areas, bars, cocktail lounges, casinos
- Retail and Wholesale Store
- School
  including classrooms, day care, kindergarten, primary and secondary schools, trade schools, training centers, colleges, universities, research areas, laboratories
- Theater
  including movie theaters, live stage performance theaters, malls, arcades, and atria
- Unknown

Again, ACMs with default occupancies must use the "unknown" occupancy category as a default.

When lighting plans are submitted for portions or for the entire building or when lighting compliance is not performed, Alternative Calculation Methods (ACMs) must model the following *area occupancy* types for spaces within an HVAC zone. These *area occupancy* types are listed in Table 2-2 of this manual. (Note: Some additional *area occupancies* are listed as subcategories of the *area occupancies* listed in Table 2-2):

- Auditorium
- Auto Repair Workshop
- Bank/Financial Institution
  including Banks, Savings & Loans, Credit Unions, Mortgage and Title Insurance
- Bar, Cocktail Lounge and Casino including cabarets, night clubs, bingo parlors and other gaming rooms with smoking
- Beauty Shop
- Barber Shop
- Classroom
  including areas for instructional purposes
- Commercial/Industrial Storage
  including warehouses and storage and stock rooms
- Commercial/Industrial Work - General, High Bay
  including manufacturing areas
- Commercial/Industrial Work - General, Low Bay

including manufacturing areas

- Commercial/Industrial Work - Precision
  Note: the use of this category is an exceptional condition and must be documented on the exceptional conditions checklist.
- Convention, Conference and Meeting Center
- Corridor, Restroom and Support Area
  including all circulation spaces, elevators, escalators, stairways, and janitorial room
- Courtrooms
- Dining Area
  including cafeterias and ballrooms
- Dry Cleaning (Coin Operated)
- Dry Cleaning (Full Service Commercial)
- Electrical, Mechanical Rooms
- Exercising Rooms and Gymnasium
  including day care, health clubs, sports arena, exercise rooms, dojos, spas, pools, saunas, and massage rooms
- Exhibit Display Area and Museum
  including art galleries
- Grocery Sales Area
- High-Rise Residential
- Hotel Function Area
- Hotel/Motel Guest Room
- Kitchen and Food Preparation
- Laundry
- Library - Reading Area
- Library - Stacks
- Lobby - Hotel
- Lobby - Main Entry
  including depots, terminals, and stations
- Lobby - Office Reception/Waiting
- Locker/Dressing Room
- Lounge/Recreation
- Mall, Arcade and Atrium
- Medical and Clinical Care
  including dental care, optical care
- Mixed Occupancy
- Office
  including accounting, counseling, art, drafting, design, insurance, stock & bond brokers, filing areas, conference rooms, mail rooms, telecommunications, and computer areas
- Other
- Religious Worship
  including churches, synagogues, temples, tabernacles, mosques, basilicas, cathedrals, missions, chapels, meditation areas, altars, shrines, worship centers, funeral homes, and memorials
- Retail Sales, Wholesale Showroom
  including pharmacies, drug stores, floral shops, video tape rentals
- Smoking Lounge
- Theater (Motion Picture)
- Theater (Performance)
  including dance halls and discotheques

- Unknown

Please note that this list is comprehensive given the categories "other" and "unknown." *Occupancies* and *area occupancies* other than those listed herein cannot be approximated by another *occupancy* or *area occupancy* unless that substitution has been approved by the Executive Director of the Commission in writing.

The selection lists accommodate unknown or miscellaneous unlisted occupancies. Any known occupancy not reasonably similar (as determined by the local building official) to an occupancy specified on a Commission-approved list is considered "other." Occupancies unknown to the applicant must use the occupancy type "unknown."

DOE Keyword: SPACE-CONDITIONS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs must require users to specify the *occupancy* of the building or the *area occupancy* of each zone being modeled. ACMs must require

the user to identify if lighting compliance is performed (lighting plans are included or have already been submitted). ACMs shall determine the occupancy type as follows:

Lighting compliance not performed. The ACM must require the user to select the *occupancy* type(s) for the building from the occupancies reported in Table 2-1 or Table 1-M of the Standards. **The ACM must use the occupancy assumptions of this Table for compliance simulations**.

Lighting compliance performed. The ACM must require the user to select the *occupancy* type(s) for each zone from the occupancies reported in Table 2-2 or Table 1-N of the Standards. **The ACM must use the *area occupancy* assumptions from Table 2-2 for compliance simulations**.

Tailored lighting and tailored ventilation are permitted as exceptional condition modifications to these default assumptions, but must be reported on the PERF-1 as exceptional conditions and on other applicable compliance forms. The tailored lighting values cannot be traded off for other features.

ACMs must use the same default assumptions, listed in Tables 2-1 through 2-6 of this manual including schedules, occupant densities, outside air ventilation rates, lighting loads, receptacle loads and service water heating loads. ACMs may have a separate occupancy list for ventilation versus other assumptions subject to the constraint that occupancy schedule types cannot be mixed. Users must select occupancy of a given space based upon the proposed or anticipated occupancy not on the amount of lighting desired. ACM input must emphasize occupancy choices and similarities not lighting choices. ACMs may <u>not</u> report the occupancy default lighting watts per square foot on the screen when the user is selecting occupancies for a space. After the occupancies are selected by the user, the lighting determined from the user's occupancy selection may appear on a separate entry screen as a default entry in the lighting power input if the user has not already entered it.

Modeling Rules for Reference Design (All): ACMs must model the same *occupancy* type(s) and *area occupancy* type(s) as the proposed building. ACMs must use the same default assumptions found in Tables 2-1 through 2-6. Tailored lighting and tailored ventilation are permitted as a modification to these default assumptions but must be reported on the PERF-1 exceptional condition list. Refer to sections for *Lighting, Ventilation, and Process Loads* for respective requirements for each of these adjustments.

2.3.1.2 Mixed Area Occupancies

Description: ACMs shall allow the user to select *mixed* as the occupancy type when selecting an area occupancy for each zone. This option shall only be available if lighting compliance is performed (lighting plans are (or have been) submitted for the zone). Refer to Chapter 4 for restrictions on selecting *mixed* as the area occupancy type.

DOE Keyword: SPACE-CONDITIONS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM must request input for the following:

1. Total area of the space

2. Area and occupancy type of up to four different area occupancy types; however, the subareas may also be optionally entered as percentages of the total area.

The ACM must automatically calculate the sum of the areas for the four different occupancies:

- If the sum of the four different areas (or percentages) is greater than the input total area of the space, the ACM must require corrected input or proportionately scale down the entries so that the sum is the total area.

- If the sum of the four different occupancies is less than the input total area, the ACM must assign the occupancy *other* to the area needed to equal the input total area.

The ACM shall assign occupancy-determined assumptions for occupant densities, outside air ventilation rates, lighting loads, receptacle loads and service water heating loads by calculating the area-weighted average for each of these inputs, using the areas input by the user. Refer to sections for *Lighting*, *Ventilation***,** and *Process Loads* for respective requirements for each of these adjustments.

ACMs shall not allow input of area occupancies with different schedules (e.g.

Nonresidential and Residential) within the same *mixed* area occupancy. However, "Corridor, Restroom, and Support Area" spaces may be part of a mixed occupancy and use the schedule of the other occupancies making up the mixed occupancy zone rather than the default schedule assigned to this occupancy type.

Modeling Rules for Reference Design (All): ACMs must use the same default assumptions calculated for the proposed design, as well as any tailored lighting, tailored ventilation, and receptacle loads input for the proposed design.

Table 2-1: Occupancy Assumptions When Lighting Plans are Submitted for the Entire Building or When Lighting Compliance is not Performed

Occupancy Type	#people 1000SF(1)	Sensible person(2)	Latent person(2)	Recept. W/SF(3)	Water Btuh person	Lighting W/SF(4)	CFM SF(5)
Commercial and Industrial Storage	5	268	403	0.43	108	0.7	0.15
Grocery Store	29	252	225	0.91	113	1.5	0.23
General Commercial and Industrial Work, High Bay	7	375	625	1.0	120	1.2	0.15
General Commercial and Industrial Work, Low Bay	7	375	625	1.0	120	1.0	0.15
Medical/Clinical	10	250	213	1.18	110	1.2	0.15
Office	10	250	206	1.34	106	1.2	0.15
Other	10	250	200	1.0	120	0.6	0.15
Religious Worship, Auditorium~~, Convention~~	136	245	112	0.96	57	1.8	1.03
Convention	136	245	112	0.96	57	1.4	1.03
Restaurant	45	274	334	0.79	366	1.2	0.38
Retail and Wholesale Store	29	252	224	0.94	116	1.7	0.23
School	40	246	171	1.0	108	1.4	0.32
Theater	130	268	403	0.54	60	1.3	0.98
Unknown	10	250	200	1.0	120	1.2	0.15

(1) Most occupancy values are based on an assumed mix of suboccupancies within the area. These values were taken from the 1994 Uniform Building Code, Table No. 10-A. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.

(2) From Table 3, p. 28.8, ASHRAE 1997 Handbook of Fundamentals

(3) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

(4) From Table 1-M of the Standards for the applicable occupancy.

(5) Developed from Section 121 and Table 1-F of the Standards.

Table 2-2: Area Occupancy Assumptions When Lighting Plans are Submitted for Portions or for the Entire Building or When Lighting Compliance is not Performed

Sub-Occupancy Type (1)	#people / 1000 SF (2)	Sensible / person (3)	Latent / person (3)	Recept. W/SF (4)	Water Btuh / person	Lighting W/SF (5)	CFM / SF (6)
All Others	10	250	200	1.0	120	0.6	0.15
Auditorium	143	245	105	1.0	60	2.0	1.07
Auto Repair Workshop	10	275	475	1.0	120	1.2	1.50
Bank/Financial Institution	10	250	250	1.5	120	1.4	0.15
Bar, Cocktail Lounge and Casino	67	275	275	1.0	120	1.1	1.50
Barber and Beauty Shop	10	250	200	2.0	120	1.0	0.40
Classroom	50	245	155	1.0	120	1.6	0.38
Courtrooms	25	250	200	1.5	120	1.1	0.19
Commercial/Industrial Storage	3	275	475	0.2	120	0.6	0.15
Commercial/Industrial Work-General, High Bay	10	275	475	1.0	120	1.2	0.15
Commercial/Industrial Work-General, Low Bay	10	275	475	1.0	120	1.0	0.15
Commercial/Industrial Work-Precision (8)	10	250	200	1.0	120	1.5	0.15
Convention, Conference and Meeting Center	67	245	155	1.0	60	~~1.6~~1.5	0.50
Corridor, Restroom, and Support Area	10	250	250	0.2	0	0.6	0.15
Dining Area	67	275	275	0.5	385	1.1	0.50
Dry Cleaning (Coin Operated)	10	250	250	3.0	120	1.0	0.30
Dry Cleaning (Full Service Commercial)	10	250	250	3.0	120	1.0	0.45
Electrical and Mechanical Room	3	250	250	0.2	0	0.7	0.15
Exercising Centers and Gymnasium	20	255	875	0.5	120	1.0	0.15
Exhibit Display Area and Museum	67	250	250	1.5	60	2.0	0.50
Grocery Sales Area	33	250	200	1.0	120	1.6	0.25
High-Rise Residential (9)	5	245	155	0.5	(7)	0.5	0.15
Hotel Function Area	67	250	200	0.5	60	2.2	0.50
Hotel/Motel Guest Room (9)	5	245	155	0.5	2800	0.5	0.15
Kitchen and Food Preparation	5	275	475	1.5	385	1.7	0.15
Laundry	10	250	250	3.0	385	0.9	0.15
Library - Reading Areas	20	250	200	1.5	120	1.2	0.15
Library - Stacks	10	250	200	1.5	120	1.5	0.15
Lobby - Hotel	10	250	250	0.5	120	~~2.2~~1.7	0.15
Lobby - Main Entry and Assembly	143	250	250	0.5	60	1.5	1.07
Lobby - Office Reception/Waiting	10	250	250	0.5	120	1.1	0.15
Locker and Dressing Room	20	255	475	0.5	385	~~0.9~~0.8	0.15
Mall, Arcade and Atrium	33	250	250	0.5	120	1.2	0.25
Medical and Clinical Care	10	250	200	1.5	160	1.4	0.15
Office	10	250	200	1.5	120	1.3	0.15
Police Station and Fire Station	10	250	200	1.5	120	0.9	0.15
Religious Worship	143	245	105	0.5	60	2.1	1.07
Retail Sales and Wholesale Showroom	33	250	200	1.0	120	2.0	0.25
Smoking Lounge	67	275	275	0.5	120	1.1	1.50
Theater (Motion Picture)	143	245	105	0.5	60	0.9	1.07
Theater (Performance)	143	245	105	0.5	60	1.4	1.07
Unknown	10	250	200	1.0	120	0.8	0.15

(1) Subcategories of these suboccupancies are described in Section 2.3.1.1 (Occupancy Types) of this manual.

(2) Values taken from the 1994 Uniform Building Code, Table No. 10-A. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.
(3) From Table 3, p. 28.8, ASHRAE 1997 Handbook of Fundamentals.
(4) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

Notes for Table 2-2 (continued)

(5) From Table 1-N of the Standards for the applicable occupancy. ACMs must use this value for the standard building design when lighting compliance is performed for the zone or area in question.
(6) Developed from Section 121 and Table 1-F of the Standards.
(7) Refer to residential water heating method.
(8) The use of this occupancy category is an exceptional condition that must appear on the exceptional conditions checklist and thus requires special justification and documentation and independent verification by the local enforcement agency.
(9) For hotel/motel guest rooms and high-rise residential spaces all these values are fixed and are the same for both the proposed design and the standard design. ACMs must ignore user inputs that modify these assumptions for these two occupancies.

2.3.1.3 Occupant Loads

Description: Based on the occupancy or area occupancy type(s) input by the user, ACMs shall determine the correct occupant density and sensible and latent heat gain per occupant.

DOE Keyword: PEOPLE-SCHEDULE
AREA/PERSON
PEOPLE-HG-SENS
PEOPLE-HG-LAT

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM shall determine the correct occupant load and sensible and latent heat gain per occupant from Table 2-1 or Table 2-2.

Modeling Rules for Reference Design (All): The standard design shall use the same occupant density and sensible and latent heat gain per occupant as the proposed design.

2.3.1.4 Receptacle Loads

Description: Based on the occupancy or area occupancy type(s) input by the user, ACMs shall determine the correct receptacle load for each occupancy type.

The receptacle load includes all equipment that are plugged into receptacle outlets. For an office occupancy the receptacle load includes all plugged-in office equipment including computer CPUs, computer monitors, workstations, and printers.

DOE Keyword: EQUIPMENT-W/SQFT
EQUIP-SCHEDULE

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM shall determine the correct receptacle load from Table 2-1 or Table 2-2.

Modeling Rules for Reference Design (All): The standard design shall use the receptacle load of the proposed design.

2.3.1.5 Process Loads

Description: Process load is the internal energy of a building resulting from an activity or treatment not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy. Process load may include sensible and/or latent components.

ACMs shall model and simulate process loads only if the amount of the process energy and the location and type of process equipment are specified in the construction documents. These information must correspond to specific special equipment shown on the building plans and detailed in the specifications. The ACM Compliance Documentation shall inform the user that the ACM will output process loads including the types of process equipment and locations on the compliance forms.

ACMs shall use the Equipment Schedules from Tables 2-4, 2-5, 2-6, or 2-7 for the operation of process equipment based on the occupancy type selected by the user.

DOE Keyword: SOURCE-TYPE
SOURCE-BTU/HR
SOURCE-SENSIBLE
SOURCE-LATENT

Input Type: Default

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs must receive input for Sensible and/or Latent Process Load for each zone in the proposed design. The process load input must include the amount of the process load (W/ft^2), the type of process equipment, and the HVAC zone where the process equipment is located. The modeled information must be consistent with the plans and specifications of the building.

Default: No Process Loads

Modeling Rules for Reference Design (All): The standard design shall use the same process loads for each zone as the proposed design.

2.3.1.6 Infiltration

Description: ACMs shall model infiltration of outdoor air through exterior surfaces.

DOE Keyword: INF-SCHEDULE
INF-METHOD
AIR-CHANGES/HR

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: Infiltration shall either be modeled as "ON" or "OFF", for each zone, according to the following:

- "OFF" if fans are ON and zone supply air quantity (including transfer air) is greater than zone exhaust air quantity.
- "ON" if fans are OFF.

When infiltration is "ON", the reference method calculates the infiltration rate as 0.038 cfm per square foot of gross exterior partition (walls and windows) area for the zone.

Modeling Rules for Reference Design (All): ACMs shall model infiltration for the standard design exactly the same as the proposed design.

2.3.2 Occupancy Lighting

2.3.2.1 Lighting

Description: ACMs shall model Lighting Power Density or LPD (in watts per square foot) for each space. Lighting loads shall be included as internal heating loads. ACMs must allocates 100% of the lighting heat to the space in which the lights occur.

ACMs shall receive an input to indicate one of the following conditions for the building:

1. *Lighting compliance not performed*. When the user indicates with the required ACM input that no lighting compliance will be performed, the ACM must require the user to select and input the occupancy type(s) of the building from Table 2-1 or 2-2. The ACM shall determine the lighting levels based on the selected occupancy type(s). An ACM must not allow the user to input any lighting power densities for the building.

   Note: ACMs may use Table 2-1 even if the building has multiple occupancies.

2. *Lighting compliance performed*. When the user indicates with the required ACM input that lighting compliance will be performed and lighting plans will be submitted for the entire building (excluding the residential units of high-rise residential buildings and hotel/motel guest rooms), the ACM must require the user to select and input the occupancy type(s) from Table 2-1 or 2-2 and enter the proposed interior lighting equipment or interior lighting power density (LPD) for the entire building. However, if lighting plans will be submitted only for portions of the building, the ACM must require the user to select and input the occupancy type(s) from Table 2-2 and enter the actual lighting levels for portions of the building with lighting plans.

ACMs must allow the user to input a Tailored Lighting Input, lighting control credits and the fraction of light heat rejected to indirectly conditioned spaces for each zone.

The Tailored Lighting Input is the lighting power density specified on prescriptively-complying set of lighting plans that is less than or equal to the allowed watts on the corresponding approved set of Tailored Lighting Forms (LTG-4). Tailored lighting inputs are designed to allow special lighting applications to comply, but to be used they must correspond to specific needs and the particular design and the plans and specifications used to meet those needs. These plans must be capable of independent compliance approval at the light levels specified.

If a value is input for the Tailored Lighting Input, the ACM shall output on the compliance forms that Tailored Lighting loads have been used in compliance and that all necessary Tailored Lighting Forms and Worksheets documenting the lighting and its justification must be provided as part of the compliance documentation and be approved independently.

If a value is input for lighting control credits, the ACM shall output on the compliance forms that lighting control credits have been used in compliance and that the lighting Control Credit Watts from Column I for Zone Total from LTG-3, for the applicable zone, Lighting Controls Credit Worksheet have been used as the lighting control credit inputs.

DOE Keyword: LIGHTING-SCHEDULE
LIGHTING-W/SQFT
LIGHT-TO-SPACE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The proposed design lighting level is restricted based on which of the above two conditions is selected by the user for the building. The proposed design lighting level is determined as follows:

1. *Lighting compliance not performed*. The proposed design lighting level shall be the lighting level listed in Table 2-1 or 2-2. ACMs must report the default lighting energy on PERF-1 and indicate that no lighting compliance was performed. ACMs **must not** print any Lighting forms.

2. *Lighting compliance performed*. The proposed design lighting level for each space shall be as follows:

   a) Nonresidential occupancies: For each space the proposed design lighting level shall be the actual lighting level of the space as shown in the construction documents and lighting compliance documentation. For each space without specified lighting level, ACMs shall select the *default* lighting level from Table 2-2 according to the occupancy type of the space.

b) High-rise residential and hotel/motel occupancies: User inputs for lighting (and lighting controls) for the residential units and hotel/motel guest rooms must be ignored and the lighting levels determined from Table 2-2 must be used.

ACMs **must** print all applicable lighting forms and report the lighting energy use and the lighting level (Watts/ft^2) for the entire project. ACMs **must** report "No Lighting Installed" for nonresidential spaces with no installed lighting. ACMs must report "Default Residential Lighting" for residential units of high rise residential buildings and hotel/motel guest rooms.

If the *modeled* Lighting Power Density (LPD) is different than the *actual* LPD calculated from the fixture schedule for the building, ACMs shall model the larger of the two values for sizing the mechanical systems and for the compliance run. ACMs shall report the larger value on PERF-1. Lighting levels shall be adjusted by any lighting Control Credit Watts, if input by the user.

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall determine standard design lighting level as follows:

1. *Lighting compliance not performed*. The standard design lighting level shall be the same as the proposed design lighting level.

2. *Lighting compliance performed*. If no Tailored Lighting Allotment is input and lighting plans will be submitted for the entire building (excluding the residential units of high-rise residential buildings and hotel/motel guest rooms), the standard design lighting level shall be determined from the same Table used for the proposed design. If lighting plans will be submitted only for portions of the building, the standard design lighting level shall be the lighting level listed in Table 2-2. If a Tailored Lighting Allotment is input, the standard design lighting level shall be the Tailored Lighting Allotment.

Modeling Rules for Reference Design (Existing Unchanged): ACMs shall determine the standard design lighting level of each space the same as it occurs in the existing design.

2.3.3 Occupancy Schedules

2.3.3.1 Schedule Types

Description: Schedules are either "Nonresidential," "Hotel Function," or "Residential."

DOE Keyword: N/A

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs must select the schedule type from Table 2-3.

Modeling Rules for Reference Design (All): The standard design shall use the same schedule type as the proposed design except for the residential units of high-rise residential buildings ~~and hotel/motel guest rooms~~ with or without setback thermostat for which the standard design shall *always* use the schedule type with setback thermostat (Table 2-6).

2.3.3.2 Weekly Schedules

Description: The reference method has three different schedules for different days of the week: (1) Weekdays, (2) Saturdays, and (3) Sundays (which includes holidays). Weekly schedules specify: a) the percentage of full load for internal gains; b) thermostat set points for heating and cooling systems; and, c) hours of operation for heating, cooling and ventilation systems.

DOE Keyword: SCHEDULE

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall use the weekly schedules in Tables 2-4 and 2-5 for nonresidential and hotel/motel occupancies respectively. For high-rise residential occupancies, ACMs shall require the user to enter whether the proposed design uses setback or non-setback thermostats for heating. ACMs shall use either Table 2-6 or Table 2-7 depending on whether the building uses setback thermostats for heating or uses non-setback thermostats.

Modeling Rules for Reference Design (All): The standard design shall use the same weekly schedules as the proposed design for nonresidential and hotel/motel occupancies. For high-rise residential occupancies the standard design shall use the weekly schedules in Table 2-6 assuming setback thermostats for the heating mode.

Table 2-3: Schedule Types of Occupancies & Sub-Occupancies

Occupancy or Sub-Occupancy Type	Schedule
Auditorium	Table 2-4: Nonresidential
Auto Repair Workshop	Table 2-4: Nonresidential
Bank/Financial Institution	Table 2-4: Nonresidential
Bar, Cocktail Lounge and Casino	Table 2-4: Nonresidential
Barber and Beauty Shop	Table 2-4: Nonresidential
Classroom	Table 2-4: Nonresidential
Courtrooms	Table 2-4: Nonresidential
Commercial/Industrial Storage	Table 2-4: Nonresidential
Commercial/Industrial Work-General	Table 2-4: Nonresidential
Commercial/Industrial Work-Precision	Table 2-4: Nonresidential
Convention, Conference and Meeting Center	Table 2-4: Nonresidential
Corridor, Restroom, and Support Area	Table 2-4: Nonresidential
Dining Area	Table 2-4: Nonresidential
Dry Cleaning (Coin Operated)	Table 2-4: Nonresidential
Dry Cleaning (Full Service Commercial)	Table 2-4: Nonresidential
Electrical and Mechanical Room	Table 2-4: Nonresidential
Exercising Centers and Gymnasium	Table 2-4: Nonresidential
Exhibit Display Area and Museum	Table 2-4: Nonresidential
Grocery Sales Area	Table 2-4: Nonresidential
High-rise Residential with Setback Thermostat	Table 2-6: Residential / with Setback
High-rise Residential without Setback Thermostat	Table 2-7: Residential / without Setback
Hotel Function Area	Table 2-5: Hotel Function
Hotel/Motel Guest Room with Setback Thermostat	Table 2-6: Residential / with Setback
Hotel/Motel Guest Room without Setback Thermostat	Table 2-7: Residential / without Setback
Kitchen and Food Preparation	Table 2-4: Nonresidential
Laundry	Table 2-4: Nonresidential
Library - Reading Areas	Table 2-4: Nonresidential
Library - Stacks	Table 2-4: Nonresidential
Lobby - Hotel	Table 2-5: Hotel Function
Lobby - Main Entry and Assembly	Table 2-4: Nonresidential
Lobby - Office Reception/Waiting	Table 2-4: Nonresidential
Locker and Dressing Room	Table 2-4: Nonresidential
Mall, Arcade and Atrium	Table 2-4: Nonresidential
Medical and Clinical Care	Table 2-4: Nonresidential
Office	Table 2-4: Nonresidential
Police Station and Fire Station	Table 2-4: Nonresidential
Religious Worship	Table 2-4: Nonresidential
Retail Sales and Wholesale Showroom	Table 2-4: Nonresidential
Smoking Lounge	Table 2-4: Nonresidential
Theater (Motion Picture)	Table 2-4: Nonresidential
Theater (Performance)	Table 2-4: Nonresidential
Unknown	Table 2-4: Nonresidential

Table 2-4: Nonresidential Occupancy Schedules

	Hour																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
HEATING (°F)																								
Weekday	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	55	55	55	55	55
Saturday	55	55	55	55	55	63	68	70	70	70	70	70	70	70	55	55	55	55	55	55	55	55	55	55
Sunday	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
COOLING (°F)																								
Weekday	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95	95	95	95
Saturday	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	95	95	95	95	95	95	95	95	95
Sunday	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
LIGHTS (%)																								
Weekday	5	5	5	5	5	5	5	5	90	90	90	90	90	90	90	90	90	90	40	5	5	5	5	5
Saturday	5	5	5	5	5	5	5	5	90	90	90	90	40	30	5	5	5	5	5	5	5	5	5	5
Sunday	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
EQUIPMENT (%)																								
Weekday	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	50	50	35	5	5	5	5	5
Saturday	5	5	5	5	5	5	5	5	25	25	25	25	25	15	5	5	5	5	5	5	5	5	5	5
Sunday	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
FANS (%)																								
Weekday	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off
Saturday	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off	off	off
Sunday	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off
INFILTRATION (%)																								
Weekday	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100
Saturday	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
Sunday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PEOPLE (%)																								
Weekday	0	0	0	0	0	0	0	5	50	50	50	30	30	50	50	50	50	50	30	0	0	0	0	0
Saturday	0	0	0	0	0	0	0	5	15	15	15	15	5	5	0	0	0	0	0	0	0	0	0	0
Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOT WATER (%)																								
Weekday	0	0	0	0	0	0	0	10	50	50	70	90	90	50	50	70	50	50	10	0	0	0	0	0
Saturday	0	0	0	0	0	0	0	10	10	20	20	20	10	10	0	0	0	0	0	0	0	0	0	0
Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2-5: Hotel Function Occupancy Schedules

	Hour																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
HEATING (°F)																								
Weekday	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
Saturday	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
Sunday	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
COOLING (°F)																								
Weekday	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
Saturday	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
Sunday	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
LIGHTS (%)																								
Weekday	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
Saturday	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
Sunday	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
EQUIPMENT (%)																								
Weekday	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
Saturday	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
Sunday	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
FANS (%)																								
Weekday	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
Saturday	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
Sunday	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
INFILTRATION (%)																								
Weekday	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
Saturday	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
Sunday	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
PEOPLE (%)																								
Weekday	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
Saturday	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
Sunday	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
HOT WATER (%)																								
Weekday	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0
Saturday	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0
Sunday	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0

Table 2-6: Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) With Setback Thermostat For Heating

	Hour																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
HEATING (°F)																								
Weekday	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
Saturday	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
Sunday	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
COOLING (°F)																								
Weekday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Saturday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Sunday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
LIGHTS (%)																								
Weekday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Saturday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Sunday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
EQUIPMENT (%)																								
Weekday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Saturday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Sunday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
FANS (%)																								
Weekday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Saturday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Sunday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
INFILTRATION (%)																								
Weekday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Saturday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sunday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PEOPLE (%)																								
Weekday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Saturday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Sunday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
HOT WATER (%)																								
Weekday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
Saturday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
Sunday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

Table 2-7: Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) Without Setback Thermostat

	Hour																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
HEATING (°F)																								
Weekday	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Saturday	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Sunday	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
COOLING (°F)																								
Weekday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Saturday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Sunday	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
LIGHTS (%)																								
Weekday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Saturday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Sunday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
EQUIPMENT (%)																								
Weekday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Saturday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Sunday	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
FANS (%)																								
Weekday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Saturday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Sunday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
INFILTRATION (%)																								
Weekday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Saturday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sunday	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PEOPLE (%)																								
Weekday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Saturday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Sunday	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
HOT WATER (%)																								
Weekday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
Saturday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
Sunday	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

2.3.3.3 Holiday Schedules

Description: The reference method has Weekdays, Saturdays and Sundays schedules which includes holidays. The 1991 calendar year is a fixed input, with January 1st being a Tuesday, and the following holidays observed:

New Year's Day	Tuesday, January 1
Martin Luther King's Birthday	Monday, January 21
Washington's Birthday	Monday, February 18
Memorial Day	Monday, May 27
Independence Day	Thursday, July 4
Columbus Day	Monday, October 14
Veteran's Day	Monday, November 11
Thanksgiving Day	Thursday, November 28
Christmas Day	Wednesday, December 25

DOE Keyword: SCHEDULE

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall use the Sunday occupancy schedule for the above holidays.

Modeling Rules for Reference Design (All): The reference design shall use the same schedule as the proposed design.

2.4 Building Systems & Plants - Required Capabilities

ACMs must have the capability to accept input for and model various types of HVAC systems. In central systems, these modeling features affect the system loads seen by the plant. A key factor related to equipment type is the energy source (electricity, natural gas, fuel oil, or LPG). For electric systems, ACMs must correctly apply the source multiplier (for example, 1 kWh = 10,239 source Btu) as stated in Table No. 1-B of the Standards.

Minimum ACM requirements for equipment that are typically used in larger systems, such as chillers, boilers, pumps and service water heaters, are described in this section.

Standard design requirements are labeled as applicable to one of the following options:

- Existing Unchanged
- Altered Existing
- New
- All

with the default condition for these four specified conditions being “All.” An ACM without the optional capability of analyzing additions or alterations must classify and report all surfaces as “All.”

2.4.1 Thermal Zoning

2.4.1.1 Thermal Zones

Description: A space or collection of spaces within a building having sufficiently similar space-conditioning requirements that those conditions could be maintained with a single controlling device.

ACMs must accept input for and be capable of modeling a minimum of fifty (50) thermal zones, each with its own thermostatic control. ACMs must also require a building level input for the number of thermostats. When the number of thermostats is not greater than twenty (20) the ACM must have one HVAC zone per thermostat. An ACM may use zone multipliers for identical zones.

When the number of zones exceeds twenty, then (and only then) thermal zones may be combined subject to a variety of rules and restrictions. See Chapter 4 for details on restrictions on combining thermal zones and requirements for zoning buildings for which no HVAC permit is sought.

DOE Keyword: ZONE
ZONE-TYPE

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference method models thermal zones as input by the user according to the plans and specifications for the building. If no thermal zones are shown on the building plans, ACMs shall inform the user to follow the guidelines described in Chapter 4--Compliance Supplement. These guidelines must be included in the ACM's Compliance Supplement and repeated in the user's manual. **It is not adequate or appropriate to reference this manual to relay this information to the user. The absence of such information and modeling rules in the ACM's user documentation is sufficient grounds for rejecting an ACM for compliance use.**

Modeling Rules for Reference Design (All): ACMs shall model the thermal zones of the reference design in the same manner as they are modeled in the proposed design.

2.4.2 Heating & Cooling Equipment

2.4.2.1 Primary Systems

Description: The ACM must be able to model the following primary systems:

- *Hydronic*. Primary system cooling/heating coil served by a central hydronic system.

- *Electric*. Primary system heating using electric resistance.

- *Fossil fuel furnace.* Primary system heating by a fossil fuel fired furnace.

- *Heat pump.* Primary system heating provided by direct expansion refrigerant coils served by a heat pump.

- *DX (Direct Expansion).* Primary system cooling provided by direct expansion refrigerant coils served by a heat pump or other compression system.

2.4.2.2 Cooling Equipment

Description: The ACM must account for variations in cooling equipment efficiency and capacity. ACMs will be compared to and tested against a reference method that also accounts for variations in efficiency and capacity as a function of part-load ratio and heat transfer fluid (e.g., chilled water, condenser water, outside air for air-cooled systems) temperatures. The ACM user must be able to explicitly enter equipment type and capacity and standard efficiency ratings (such as SEER and/or EER for packaged equipment).

In certain cases the standards allow cooling equipment to be installed below the mandatory minimum efficiency ratings listed in the standards for new currently manufactured equipment, e.g. existing equipment moved to a new location in the building. If an ACM allows efficiencies to be entered (optional entry and capability) lower than those indicated in the mandatory features for newly manufactured equipment, then those entries must also be indicated in the exceptional conditions checklist on the PERF-1 and be justified in writing.

ACMs must model two fundamental types of cooling equipment:

1. *Water chillers.* Cooling equipment that chills water to be supplied to building coils.

2. *Direct expansion (DX) compressors.* Cooling systems that directly cool supply air without first cooling a heat transfer medium such as water. See descriptions above for other definitions.

The reference method models part-load performance for at least two different types of water chillers and **all ACMs must allow the user to select either of these two chiller types**:

1. *Centrifugal.* Compression refrigeration system using rotary centrifugal compressor.

2. *Reciprocating.* Compression refrigeration system using reciprocating positive displacement compressor.

2.4.2.3 Heating Equipment

Description: The ACM must account for variations in heating equipment performance according to efficiency and as a function of load. The user must be able to explicitly enter equipment type and capacity and rated efficiency (such as AFUE, Steady State Thermal Efficiency or HSPF).

In certain cases the standards allow heating equipment to be installed below the mandatory minimum efficiency ratings listed in the standards for new currently manufactured equipment, e.g. existing equipment moved to a new location in the building. If an ACM allows efficiencies to be entered (optional entry and capability) lower than those indicated in the mandatory features for newly manufactured equipment, those entries must also be indicated in the exceptional conditions checklist on the PERF-1 and be justified in writing.

ACMs must model three fundamental types of heating equipment:

1. *Furnaces*. The following forced air furnaces must be provided:

   - *Electric*. Electric resistance elements used as the heating source.
   - *Fossil Fuel*. Natural gas or liquid propane is used as the heating source.

2. *Boilers*. The following capabilities must be provided for boilers:

   - *Electric*. Boiler uses electric resistance heating.
   - *Fossil Fuel*. Boiler is natural gas or oil fired.
   - *Natural draft*. Fossil fired boiler uses natural draft (atmospheric) venting.
   - *Forced/induced draft*. Fossil fired boiler uses fan forced or induced draft venting. With this option, the ACM must account for fan energy.
   - *Hot water*. Boiler produces hot water.

3. *Heat Pumps*. Supply air is heated through direct expansion process utilizing electricity as the fuel type and outside air as the heat source.

2.4.2.4 Standard Design Systems

Description: The reference method will assign one of five *Standard Design System* types for all proposed HVAC systems in order to establish an energy budget for the standard building. This system is generated and modeled for all buildings, even if no mechanical heating or cooling is included in the building permit.

ACMs must require the user to input the following for each system:

1. **Building Type** - low-rise nonresidential, high-rise nonresidential, residential and hotel/motel guest room

2. **System Type** - single zone, multiple zone

3. **Heating Source** - fossil fuel, electricity

4. **Cooling Source** - hydronic, other (for high-rise residential and hotel/motel guest room, only)

The following definitions apply to the terms listed above:

Low-rise nonresidential: A building which is of occupancy group A, B, E, or H with three or less habitable stories.

High-rise nonresidential: A building which is of occupancy group A, B, E, or H with four or more habitable stories

High-rise residential: A building, other than a hotel/motel, of occupancy group R-1 with four or more habitable stories.

Hotel and motel guest room: The guest rooms of a Hotel/Motel as defined in Section 101(b) of the Standards.

Single zone: A supply fan (and optionally a return fan) with heating and cooling heat exchangers (e.g. DX coil, chilled water coil, hot water coil, furnace, electric heater) that serves a single thermostatic zone. This system may or may not be constant volume.

Multiple zone: A supply fan (and optionally a return fan) with heating and/or cooling heat exchangers (e.g. DX coil, chilled water coil, hot water coil, furnace, electric heater) that serves more than one thermostatic zone. Zones are thermostatically controlled by features including but not limited to variable volume, reheat, recool and concurrent operation of another system.

Fossil fuel: At least one source system heat is from a fossil fuel such as gas, oil, or coal.

Electric: Heating source is from electrically powered systems only such as electric resistance, heat pumps with no auxiliary heat or with electric auxiliary heat, solar with electric back-up, etc.

Hydronic: Any cooling system which uses water or a water solution as a source of cooling or heat rejection, including chilled water systems (both air and water-cooled) as well as water-cooled or evaporatively cooled direct expansion systems such as water source (water-to-air) heat pumps.

All ACMs must accept input for and be able to model the following system types for both the standard and proposed design:

- **System 1: Packaged Single Zone (PSZ), Gas furnace and electric air conditioner**

- **System 2: Packaged Single Zone (PHP), Electric heat pump and air conditioner**

- **System 3: Packaged Variable Air Volume (PVAV), Central gas boiler with hydronic reheat and electric air conditioner**

- **<u>System 4</u>: Built-up Variable Air Volume (VAV), Central gas boiler with hydronic reheat and central electric chiller with hydronic air conditioning**

- **<u>System 5</u>: Four-pipe fan coil (FPFC), Central gas boiler and electric chiller serving individual units with hydronic heating and cooling coils.**

DOE Keyword: SYSTEM-TYPE

Input Type: Prescribed

Tradeoffs: N/A

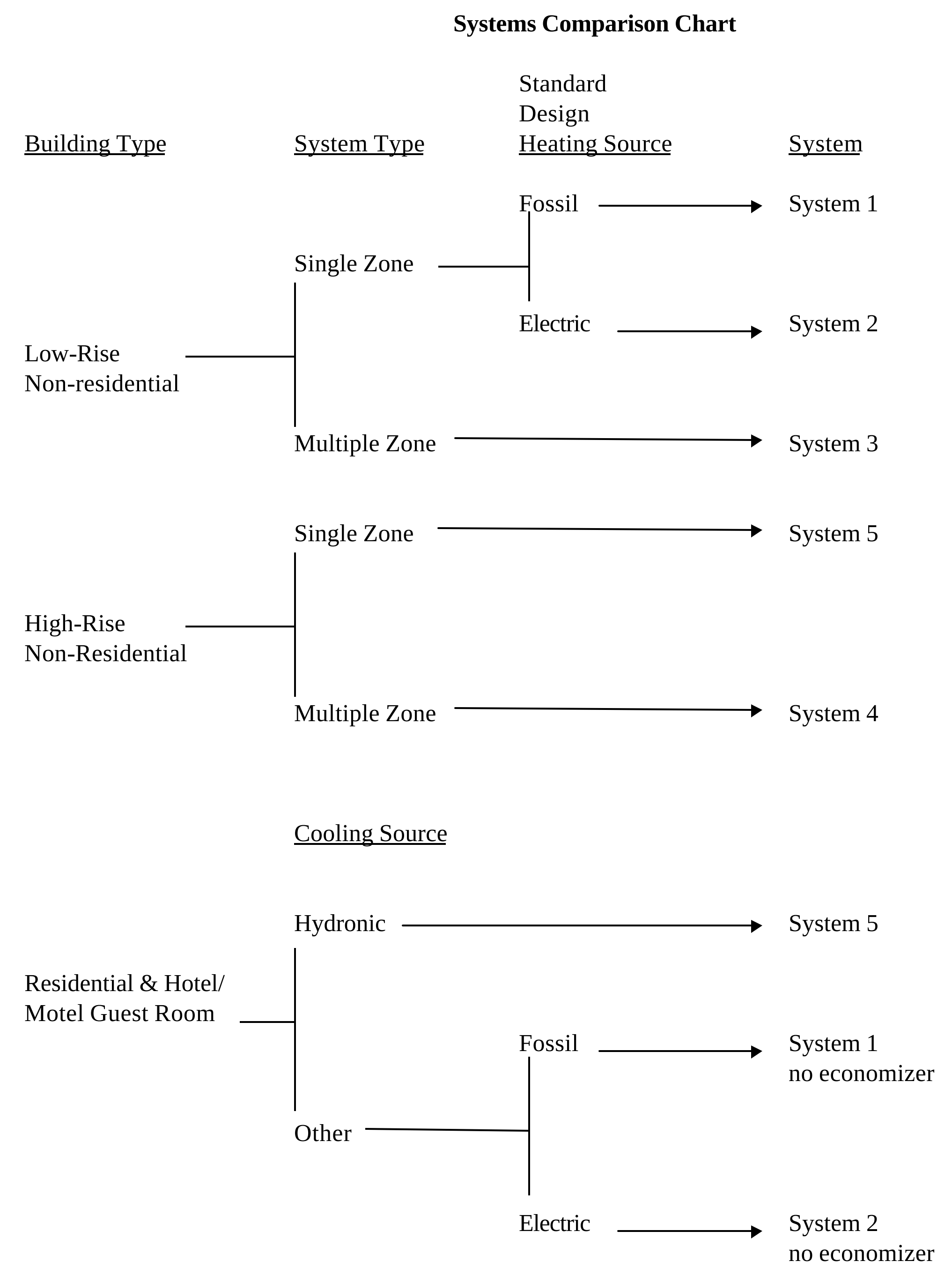
Modeling Rules for Proposed Design: The proposed system shall be input as it is shown in the construction documents for the building.

ACMs must receive enough input about the proposed system to: 1) generate the applicable standard design system; 2) apply all required efficiency descriptors to both the standard and proposed designs; and, 3) model the energy use of the proposed design accurately.

Modeling Rules for Reference Design (New): The reference design system selection is shown in Figure 2-1. The reference method chooses the standard HVAC system only from the five minimum systems listed above. The reference method will select its standard system according to Figure 2-1, for the standard design system, regardless of the system type chosen for the proposed design. For example, a hydronic heating system served by a gas-fired boiler to supply hot water to the loop for a low-rise nonresidential building is considered a single zone (fan) system with fossil fuel for a heating source, and would be compared to System #1 - a Packaged Single Zone Gas/Electric System. Likewise a gas-fired absorption cooling system with a gas-fired furnace serving a single zone would be compared to System #1 also. Figures 2-2a through 2-2d describe the five standard design system types.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing) : The reference design shall model the existing system with its rated efficiency. If the entered efficiency is lower than those indicated in the mandatory features for newly manufactured equipment, then those entries must also be indicated in the exceptional conditions checklist on the PERF-1 and be noted as existing system.

Figure 2-1: Standard Design System Selection Flowchart



Standard Design Systems

System 1:	Packaged Single Zone, Gas/Electric
System 2:	Packaged Single Zone, Heat Pump
System 3:	Packaged VAV, Gas Boiler with Reheat
System 4:	Central VAV, Gas Boiler with Reheat
System 5:	Four Pipe Fan Coil System with Central Plant

Figure 2-2a: System #1 and System #2 Descriptions

System Description:	Packaged Single Zone with Gas Furnace/Electric Air Conditioning (#1) or Heat Pump (#2)
Supply Fan Power:	See Section 2.4.2.22
Supply Fan Control:	Constant volume
Min Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum SEER or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp:	$85 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace (#1) or heat pump (#2)
Heating Efficiency:	Minimum AFUE, Thermal Efficiency, COP or HSPF based on equipment type and output capacity of proposed unit(s).
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm
Ducts:	For ducts installed in spaces between insulated ceiling and roof or exterior to the building, the duct system efficiency shall be as described in Section 2.4.2.35

Figure 2-2b: System #3 Description

System Description:	Packaged VAV with Boiler and Reheat
Supply Fan Power:	See Section 2.4.2.22
Supply Fan Control:	Individual VAV supply fan with 25 horsepower and less: VAV - forward curved fan with discharge damper Individual VAV supply fan greater than 25 horsepower: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

Figure 2-2c: System #4 Description

System Description:	Chilled Water VAV With Reheat
Supply Fan Power:	See Section 2.4.2.22
Supply Fan Control:	Individual VAV supply fan with 25 horsepower and less: VAV - forward curved fan with discharge damper Individual VAV supply fan greater than 25 horsepower: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Chilled water
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

Figure 2-2d: System #5 Description

System Description:	Four-Pipe Fan Coil With Central Plant
Supply Fan Power:	See Section 2.4.2.22
Minimum Supply Temp:	$50 \le T \le 60$ DEFAULT: 55
Cooling System:	Chilled water
Cooling Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Maximum Supply Temp:	$90 \le T \le 110$ DEFAULT: 100
Heating System:	Gas boiler
Heating Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

2.4.2.5 Combining Like Systems

Description: When several similar thermal zones with similar *heating/cooling units* are combined (see Section 4.3.3.1 for conditions that lead to thermal zones being similar) or similar *heating/cooling units* with similar controls serve a thermal zone, the ACM may combine the system heating and cooling capacities, supply air flow rates, and fan power for the zone.

The ACM must require the user to input the number of such systems. The ACM shall receive a value for this input for fan systems, packaged heating or cooling equipment, chillers and boilers. The efficiency of the combined system shall be the weighted average of efficiencies of all systems based on the size of each unit.

If the user inputs a value greater than 1 for the *number of heating/cooling units*, the ACM must print a warning on the Performance Summary form, PERF-1, indicating that systems of similar type have been modeled as one system and that a prescriptive Mechanical Equipment Summary form, MECH-3, must be attached documenting each individual system. Refer to Chapter 4, Section 4.3.3.19 for discussion of allowed like system types.

DOE Keyword: N/A

Input Type: Default

Tradeoffs: N/A

Modeling Rules for Proposed Design: The reference program shall model one heating/cooling unit with heating and cooling capacities, supply air flow rate, and fan power equal to the total capacities, air flow rates, and fan power of the combined systems. The efficiency shall be equal to the capacity weighted average efficiency for the systems being combined.

Default: One system

Modeling Rules for Reference Design (All): The reference program shall model the standard design using *Standard Design System* types and the applicable capacities, supply air flow rate, fan power, and the minimum efficiency requirements.

2.4.2.6 Equipment Performance Curves (except for electric chillers)

Description: The reference method will model the performance curves of mechanical heating and cooling equipment as functions of variables such as part-load ratio, outside dry-bulb and wet-bulb temperatures, return air dry-bulb and wet-bulb temperatures and air flow rate. These reference method performance curves are those specified in the DOE 2 Reference Manual (Version 2.1E) Supplement, Lawrence Berkeley Laboratory Document #LBL-8706, Rev. 5. The performance curves for electric chillers are discussed in Section 2.4.2.33.

DOE Keyword: CURVE-FIT

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference method will use the performance curves for equipment specified in the DOE 2 Reference Manual (Version 2.1E) Supplement or other default relationships as specified in this manual.

Modeling Rules for Reference Design (All): The reference method will use the same performance curves as the proposed design.

2.4.2.7 Cooling Efficiency of DOE Covered Air Conditioners

Description: ACMs must require the user to input the SEER (seasonal energy efficiency ratio) of any DOE-covered consumer product. ACMs must allow the user to input the EER (energy efficiency ratio), however the ACM must not require this input for HVAC equipment that is covered by the U.S. DOE appliance standards.

ACMs must also use the ARI net cooling capacity input by the user, as required by this chapter, and the ARI tested fan power and part load capacity as calculated according to this chapter. These three values are also necessary to model efficiency of DOE-covered consumer products.

Modeling of SEER is achieved through accounting for the Electrical Input Ratio, EIR, and total system cooling capacity as functions of Outside Dry-Bulb (ODB) and Coil Entering Wet-Bulb (WB) temperatures, and through accounting for duct efficiency impacts on EIR.

The reference method is based on a created performance curve, similar to the DOE 2.1

curve COOL-EIR-FT, using the following points for WB, ODB and N_{eir}, respectively. This new curve is given below in terms of the reference computer program curve-fit instruction. For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the COOL-EIR-SEER shall be divided by the seasonal distribution efficiency as determined in Section 2.4.2.35.

COOL-EIR-SEER = CURVE-FIT
TYPE = BI-QUADRATIC
DATA = (67,95,1.0)
(67,82,N_{eirb})
(67,110,1.174)
(67,105,1.113)
(67,70,$N_{eir70/67adj}$)
(80,95,0.897)
(50,95,1.070) ..

where N_{eirb} and $N_{eir70/67adj}$ are calculated as follows:

1. ACMs must first calculate an EER_b from the following equation:

$$EER_b = \frac{SEER}{1 - 0.5 \times C_d}$$

Equation 2.4.1

where:

EER_b = Energy Efficiency Ratio at DOE part-load conditions. [Btuh/watt]

C_d = Cyclical degradation coefficient at DOE part-load conditions

2. If the EER is not input, calculate EER from the following equation:

$$EER = 0.855 \times EER_b$$

Equation 2.4.2

3. Calculate the electrical input ratio, EIR_a, at ARI conditions according to the following equation:

$$EIR_a = \frac{(CAP_a / EER) - ARIFanPower}{(CAP_a / 3.413) + ARIFanPower}$$

Equation 2.4.3

ARI Fan Power = The power [watts] used by the supply fan for the purpose of performing ARI, CEC and DOE approved tests (See ***ARI Fan***

Power.)

CAP_a = The net cooling capacity at ARI conditions of 95 outside dry-bulb(ODB) and 67 coil entering wet-bulb (WB) [Btuh]

4. Calculate the electrical input ratio, EIR_b, at ARI part-load conditions according to the following equation:

$$EIR_b = \frac{(CAP_b / EER_b) - ARIFanPower}{(CAP_b / 3.413) + ARIFanPower}$$

Equation 2.4.4

where:

EER_b = From Equation 2.4.1 above. [Btuh/watts]

EIR_b = The electrical input ratio [unitless], or cooling electrical efficiency of the piece of equipment at ARI part-load conditions

CAP_b = The net cooling capacity [Btuh] at ARI part-load conditions (82 ODB and 67 WB), given by the following equation:

$$CAP_b = 1.07 \times CAP_a$$

Equation 2.4.5

where

CAP_a= The net cooling capacity [Btuh] at ARI conditions of 95 outside dry-bulb (ODB) and 67 coil entering wet-bulb (WB)

5. Normalize EIR_b based on ARI conditions, 95 outside dry-bulb (ODB):

   $N_{eirb} = EIR_b/EIR_a$ [unitless]

6. Calculate $N_{eir70/67adj}$ according to the following equation:

   $N_{eir70/67adj} = 0.876 \, H \, N_{eirb}$ [unitless]

For heat pumps, the reference method uses performance curves based on the ratio of the COPs and CAPACITIES at 47^{o}F and at 17^{o}F (COP_{47}, COP_{17}, CAP_{47}, CAP_{17}) and creates new performance curves, similar to the DOE 2.1 COOL-EIR-FT and COOL-CAP-FT, using the following points for ODB and the COPs and CAPACITIES at these temperatures. <u>For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HP-EIR-FT shall be divided by the seasonal distribution efficiencies as determined in Section</u>

2.4.2.35.

HP-EIR-FT = CURVE-FIT
TYPE = CUBIC
DATA = (67,0.856)
(57,0.919)
(47,1.000)
(17,COP_{47}/COP_{17})
(7,1.266×COP_{47}/COP_{17})
(-13, 3.428) ..

HP-CAP-FT = CURVE-FIT
TYPE = CUBIC
DATA = (67,1.337)
(57,1.175)
(47,1.000)
(17,CAP_{17}/CAP_{47})
(7,0.702×CAP_{17}/CAP_{47})
(-13, 0.153) ..

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall require users to input a value for SEER and shall allow users to input a value for EER. ACMs shall use 0.03 for the cyclical degradation coefficient C_d. The reference method uses user input values to generate the required performance curves for the proposed design.

Default: Minimum SEER and EER as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The ACM shall assign standard design performance data for the above functions according to the following criteria:

a) If the proposed design system is a *single package* unit according to the CEC Appliance Efficiency Standards, the standard design shall use an EER of 8.6, an SEER of 9.9 and a C_d of 0.03 to develop the required performance curves.

b) If the proposed design system is a *split system* according to the CEC Appliance Efficiency Standards, the standard design shall use an EER of 8.7, an SEER of 10.0 and a C_d of 0.03 to develop the required performance curves.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): The ACM shall assign standard design performance data for the above functions according to the following criteria:

a) If the existing system is a *single package* unit according to the CEC Appliance Efficiency Standards, the standard design shall use the EER or the SEER of the existing system and a C_d of 0.03 to develop the required performance curves.

b) If the existing system is a *split system* according to the CEC Appliance Efficiency Standards, the standard design shall use the EER or the SEER of the existing system and a C_d of 0.03 to develop the required performance curves.

The ACM shall use the ARI fan power of the existing system.

2.4.2.8 Cooling Efficiency of Packaged Equipment not Covered by DOE Appliance Standards

Description: ACMs shall require the user to input the EER for all packaged cooling equipment that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net cooling capacity, CAPa, at ARI conditions for all cooling equipment.

For equipment where supply fan energy is included in the calculation of EER and CAPa, the reference method shall calculate the electrical input ratio, EIR, according to Equation 2.4.4.
<u>For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the COOL-EIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.4.2.35.</u>

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI conditions for all equipment documented in the plans and specifications for the building.

Default: Minimum EER as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): For the reference method, the standard design shall assign the EER and EIR of each unit according to the applicable requirements of the Appliance Efficiency Standards or the Standards. The EIR of the equipment will be based on the proposed system with an EER that meets the applicable requirements of the Standards but has the same cooling capacity and ARI fan power as the unit selected for the proposed design.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall use the EER, EIR, and the ARI fan power of the existing system. The EIR of the existing equipment must be based on the EER and the ARI fan power of the existing system.

2.4.2.9 Efficiency of Cooling Equipment Included in Built-up Systems

Description: ACMs must require the user to input: (1) the type of central cooling plant equipment proposed (e.g. open centrifugal, open reciprocating, water chiller, direct expansion, etc.); (2) the number of central cooling units and the capacity of each unit; (3) the efficiency of each central cooling unit; and (4) the type of refrigerant to be used in each central cooling unit. ACMs shall not accept user-defined performance curves for any equipment except for electric chillers.

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI test conditions for all equipment documented in plans and specifications for the building.

Default: Minimum efficiency as specified in the Appliance Efficiency Regulations or Tables 1-C1 through 1-C7 of the Building Energy Efficiency Standards

Modeling Rules for Reference Design (New): Based on the capacity and type of chiller(s) the reference method assigns the EER of each unit of the standard design according to the applicable requirements of the Appliance Efficiency Standards or the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall use the EER and the ARI fan power of the existing system.

2.4.2.10 Heating Efficiency of DOE Covered Heat Pumps

Description: ACMs must require the user to input: (1) the Heating Seasonal Performance Factor (HSPF); (2) the heating capacity at 47 ODB; and, (3) the system configuration, either *single package* unit or *split system* for DOE covered heat pumps.

The reference method calculates an equivalent Coefficient Of Performance (COP) according to the following:

a) For *single package* units:

$$COP = \left(0.2778 \times HSPF + 0.9667\right)$$

Equation 2.4.6a

b) For *split systems*:

$$COP = \left(0.4813 \times HSPF - 0.2606\right)$$

Equation 2.4.6b

The reference method will calculate the total heating capacity at ARI conditions, $HCAP_{atot}$ of the heat pump according to the following equation:

$$HCAP_{atot} = HCAP_{a} - \left(3.413 \times ARIFanPower\right)$$

Equation 2.4.7

where the total capacity, $HCAP_{atot}$ is given in Btu per hour [Btuh] and ARIFanPower is rated in watts.

The reference method calculates the electrical heating input ratio, HIR, according to the following equation:

$$HIR = \frac{[HCAP_a / (COP \times 3.413)] - ARIFanPower}{(HCAP_a / 3.413) - ARIFanPower}$$

Equation 2.4.8

For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HEATING-EIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.4.2.35.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input all required data, as it occurs in the construction documents.

Default: Minimum COP as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The reference method and all ACMs shall assign a COP of 2.8 to standard design *single package* units and 3.0 to standard design *split systems*.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall use the COP and the ARI fan power of the existing system.

2.4.2.11 Heating Efficiency of Heat Pumps not Covered by DOE Standards

Description: ACMs shall require the user to input the COP for all packaged heat pump equipment with fans that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net heating capacity, $HCAP_a$, at ARI conditions for all equipment.

The reference method calculates the electrical heating input ratio, HIR, according Equation 2.4.8.

For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HEATING-HIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.4.2.35.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in either the Appliance Efficiency Regulations or Table 1-C2 of the Building Energy Efficiency Standards.

Modeling Rules for Reference Design (New): For the reference method, the HIR of each unit in the standard design is determined according to the applicable requirements of the Appliance Efficiency Standards or the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the COP and the ARI fan power of the existing system.

2.4.2.12 Heating Efficiency of DOE Covered Fan Type Central Furnaces

Description: ACMs shall require the user to input: (1) the AFUE; (2) the heating capacity; and (3) the system configuration for all DOE covered fan type central furnaces.

The reference method calculates an equivalent heating input ratio, HIR, according to the following:

a) For *single package* units:

$$HIR = (0.005163 \times AFUE + 0.4033)^{-1}$$

Equation 2.4.9a

b) For *split systems* with AFUEs not greater than 83.5:

$$HIR = (0.002907 \times AFUE + 0.5787)^{-1}$$

Equation 2.4.9b

c) For *split systems* with AFUEs greater than 83.5:

$$HIR = (0.011116 \times AFUE - 0.098185)^{-1}$$

Equation 2.4.9c

For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HEATING-HIR shall be divided by the seasonal efficiencies as determined in Section 2.4.2.35.

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall require the user to input the AFUE of each DOE covered central furnace.

Default: Minimum AFUE as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The reference method assigns an HIR of 1.24 to all standard design heating systems when a fan-type central furnace is the proposed heating system.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.13 Heating Efficiency Fan Type Central Furnaces not Covered by DOE Standards

Description: The ACM shall require the user to input the steady state efficiency, or the HIR, of each furnace for each furnace's rated capacity.
<u>For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HEATING-HIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.4.2.35.</u>

DOE Keyword: HEATING-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.

Default: Minimum COP as specified in <u>either</u> the Appliance Efficiency Regulations <u>or Table 1-C5 of the Building Energy Efficiency Standards</u>.

Modeling Rules for Reference Design (New): The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.14 Efficiency of Boilers Covered by DOE Standards

Description: ACMs must require the user to input: (1) the type of central boiler proposed (steam or water, forced or induced draft, etc); (2) the number of central boilers and the capacity of each unit; (3) the heating input ratio of each boiler; and (4) the type of primary fuel used in each boiler. ACMs shall use the same boiler part-load curve for the proposed and standard designs. The reference method uses the DOE 2.1E default part-load curves for boilers. **ACMs are not allowed to accept user-defined part-load curves for boilers.**

ACMs shall calculate an equivalent heating input ratio, HIR, according to the following:

(a) $75 \leq AFUE < 80$

$$HIR = (0.1 \times AFUE + 72.5)^{-1} \times 100$$

Equation 2.4.10a

(b) $80 \leq AFUE < 100$

$$HIR = (0.875 \times AFUE + 10.5)^{-1} \times 100$$

Equation 2.4.10b

DOE Keyword: BOILER-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The reference method converts, to an HIR, the user input AFUE as documented in the plans and specifications for the building.

Default: Minimum AFUE as specified in the Appliance Efficiency Regulations

Modeling Rules for Reference Design (New): The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.15 Efficiency of Boilers not Covered by DOE Standards

Description: ACMs must require the user to input: (1) the type of central boiler proposed (steam or water, forced or induced draft, etc); (2) the number of central boilers and the capacity of each unit; (3) the heating input ratio of each boiler; and (4) the type of primary fuel used in each boiler. ACMs shall use the same boiler part-load curve for the proposed and standard designs. The reference method uses the DOE 2.1E default part-load curves for boilers.

DOE Keyword: BOILER-HIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at required testing conditions for all equipment documented in the plans and specifications for the building and shall model all combustion air fans as input by the user.

Default: Minimum AFUE as specified in either the Appliance Efficiency Regulations or efficiency as specified in Table 1-C6 of the Building Energy Efficiency Standards.

Modeling Rules for Reference Design (New): The standard design shall use a boiler or boilers with an AFUE as specified in either the Appliance Efficiency Regulations or efficiency as specified in Table 1-C6 of the Building Energy Efficiency Standards ~~HIR of 1.25~~ in the reference method.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.4.2.16 Air-Cooled Condensers

Description: The reference method shall model air-cooled condensers as integral to the cooling plant equipment specified. Direct expansion compressors with air-cooled condensers shall include the EIR of the condenser with the EIR of the compressor. Air-cooled water chillers shall include the EIR of the condenser with the EIR of the chiller. The EIR shall be calculated according to Equation 2.4.3, except when supply/return fan heat is excluded by the manufacturer when calculating the EER. In that case, the EER shall be calculated according to the following equation:

$$EIR_a = \frac{(CAP_a / EER)}{(CAP_a / 3.413) + ARIFanPower}$$

Equation 2.4.3

Refer to Section 2.4.2.31 (Chiller Characteristics) for modeling rules for air-cooled chillers.

2.4.2.17 Electric Motor Efficiency

Description: The full-load efficiency of the electric motor established in accordance with NEMA Standard MG1. The standard design shall use the minimum nominal full-load efficiency shown in Table 2-8. For systems with multiple motors, the reference program combines the mechanical efficiencies as follows:

$$MEFF_{combine} = \frac{\sum_{i=1}^{n} (HP_i \times MEFF_i)}{\sum_{i=1}^{n} HP_i}$$

where

$MEFF_{combine}$ = Combined mechanical efficiency
$MEFF_i$ = Mechanical efficiency of the i^{th} motor
HP_i = Horsepower of the i^{th} motor
n = Total number of motors being combined

DOE Keyword: SUPPLY-MECH-EFF
RETURN-EFF

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input the full-load efficiency for all electric motors documented in the plans and specifications for the building as established in accordance with NEMA Standard MG1.

Default: Standard motor efficiency from Table 2-8.

Modeling Rules for Reference Design (New): The reference design shall use the appropriate minimum efficiency values from Table 2-8.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): The reference design shall use the full-load efficiency of existing electric motors as established in accordance with NEMA Standard MG1. If the efficiency of the existing motor is not available the reference design shall use the default motor efficiency from Table 2-8.

Table 2-8: Minimum Nominal Efficiency for Electric Motors (%)

	Open Motors				Enclosed Motors			
Number of Poles	**2**	**4**	**6**	**8**	**2**	**4**	**6**	**8**
Synchronous Speed	**3600**	**1800**	**1200**	**900**	**3600**	**1800**	**1200**	**900**
Motor Horsepower								
1	-	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5

7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.0	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	-	95.4	95.4	95.0	-
350	95.0	95.4	95.4	-	95.4	95.4	95.0	-
400	95.4	95.4	-	-	95.4	95.4	-	-
450	95.8	95.8	-	-	95.4	95.4	-	-
500	95.8	95.8	-	-	95.4	95.8	-	-

2.4.2.18 ARI Fan Power

Description: The *ARI Fan Power* is required to calculate the electrical input ratios described above. The reference method determines the *ARI Fan Power* for systems 1, 2 and 3 by assuming that the *ARI Fan Power* is fixed at 365 watts per 1000 cfm with supply air flow rate fixed at 400 cfm per 12,000 Btuh net cooling capacity.

2.4.2.19 Fan System Configuration

Description: ACMs must model the configuration of fan systems as described below.

DOE Keyword: FAN-PLACEMENT
MOTOR-PLACEMENT

Input Type: Prescribed

Tradeoffs: N/A

Modeling Rules for Proposed Design: The proposed design system shall assume the following:

- For systems 1 through 4, all supply fans shall be "draw-through" type, positioned downstream from all heating and cooling sources.
- For system 5, the supply fan shall be a "blow-through " type, positioned upstream from heating and cooling sources.
- ACMs may combine return fans with the supply fan if and only if the controls are of the same type. For example, ACMs may combine fans if they all have variable speed drive control or if they all are constant volume fans.

  Return fans are those that are required to operate at design conditions to draw air from conditioned zones and can either return that air back to the source (the intake of the supply fan system) or exhaust it to the outdoors. Exhaust fans that are manually switched such as bathroom fans must not be included in the fan model.

- All fan motor heat shall be rejected to the supply air stream

.

Modeling Rules for Reference Design (All): All standard design fan configuration features shall be the same as the proposed design.

2.4.2.20 Fan System Operation

Description: Operating schedule of fan systems are in Tables 2-4 through 2-7. Fan systems shall operate continuously (turned on) during scheduled operation hours for all occupancy types **except** for the residential units of high-rise residential buildings and hotel/motel guest rooms. In these occupancies, the user may model the fan operation either as *continuous* or *intermittent*. For continuous fan operation, the fan operates during scheduled operation hours regardless of whether heating or cooling is needed. For intermittent fan operation, the fan operates only when heating or cooling is needed. The DOE-2 Keyword for intermittent fan operation is:

INDOOR-FAN-MODE = INTERMITTENT

The DOE-2 Keyword for continuous fan operation is:

INDOOR-FAN-MODE = CONTINUOUS

DOE Keyword: FAN-SCHEDULE
INDOOR-FAN-MODE
NIGHT-CYCLE-CONTROL

Input Type: Default

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall model the fan operation as *continuous* for all occupancy types during scheduled operation hours except for the residential units of high-rise residential buildings and hotel/motel guest rooms. For these occupancies, ACMs shall accept input for the type of fan operation (*continuous* or *intermittent)*.

Default: INDOOR-FAN-MODE = CONTINUOUS

Modeling Rules for Reference Design (All): Standard design fan system operation shall be identical to the proposed design except when the user specifies electric resistance heating without a fan system for residential units of high-rise residential buildings and hotel/motel guest rooms. In such cases the reference design fan operation shall be *intermittent*.

2.4.2.21 Fan Volume Control

Description: ACMs must be capable of modeling the electrical input ratio, EIR, of supply and return fans for systems 3 and 4 as a function of the part-load-ratio (the ratio of supply air rate at any given time to the supply air rate at design maximum conditions). All ACMs that explicitly model variable air volume HVAC systems must require the user to input the type of fan volume control for each supply/return fan combination of the proposed. Minimum required fan volume controls and associated part-load-curves are given below in the form of DOE 2.1 curve-fit instructions.

- *Constant volume*. Fan supplies a constant volume of air at constant power draw whenever it is in operation. This system does not have a part-load-curve.
- *Forward curved centrifugal fan with discharge dampers*. Variable volume fan with static pressure control dampers at the fan outlet or with no direct static pressure control.

```
FC-FAN-W/DAMPERS = CURVE-FIT
TYPE = QUADRATIC
OUTPUT-MIN = 0.22
DATA =          (.0,1.0)
                  (0.9,0.88)
                  (0.8,0.75)
                  (0.7,0.66)
                  (0.6,0.55)
                  (0.5,0.47)
                  (0.4,0.40)
                  (0.3,0.33)
                  (0.2,0.27)  ..
```

- *Forward curved centrifugal fan with inlet vanes*. Variable volume fan with static pressure flow controlled by vanes at the fan inlet.

```
FC-FAN-W/VANES = CURVE-FIT
TYPE = QUADRATIC
OUTPUT-MIN = 0.22
DATA =          (1.0,1.0)
                  (0.9,0.78)
                  (0.8,0.60)
                  (0.7,0.48)
                  (0.6,0.38)
                  (0.5,0.29)
                  (0.4,0.24)
                  (0.3,0.23)
                  (0.2,0.22)  ..
```

- *Air foil centrifugal fan with inlet vanes.* Fan is controlled by variable inlet vanes.

```
AF-FAN-W/VANES = CURVE-FIT
TYPE = QUADRATIC
OUTPUT-MIN = 0.48
DATA =          (1.0,1.0)
                  (0.9,0.83)
                  (0.8,0.71)
                  (0.7,0.66)
                  (0.6,0.60)
                  (0.5,0.55)
                  (0.4,0.52)
```

(0.3,0.48) ..

- *Variable speed drive*. Variable volume fan of any type with static pressure control by an AC frequency invertor varying fan speed.

```
ANY-FAN-W/VSD = CURVE-FIT
TYPE = QUADRATIC
OUTPUT-MIN = 0.10
DATA =        (1.0,1.0)
               (0.9,0.78)
               (0.8,0.57)
               (0.7,0.40)
               (0.6,0.29)
               (0.5,0.20)
               (0.4,0.15)
               (0.3,0.11)
               (0.2,0.10) ..
```

DOE Keyword:	FAN-CONTROL
Input Type:	Prescribed
Tradeoffs:	N/A
Modeling Rules for Proposed Design:	The ACM shall model the same fan volume control for proposed systems as documented in the plans and specifications for the building. The user may not enter part-load curves for fans or other HVAC equipment.
Modeling Rules for Reference Design (New):	ACMs shall assume a *variable speed drive* for fan volume control for each proposed fan in standard design systems 3 and 4 when the fan motor is greater than 25 horsepower. For systems 1, 2, and 5, ACMs shall assume the same fan volume control as the proposed design.
Modeling Rules for Reference Design (Existing Unchanged & Altered Existing):	ACMs shall use the existing fan volume control for the reference design.

2.4.2.22 Design Fan Power Demand

Description: ACMs must model the fan system power demand for all fans in the system that are required to operate at *design* conditions in order to supply air from the source to the conditioned space and to return it back to the source or to exhaust it to outdoors. The reference program models the fan system power demand using Fan Power Index (FPI). Fan power index is defined as the hourly power consumption of the fan system per unit of air moved (Watts per cfm).

For each supply fan and each return fan system (except for the fan-coil system serving the residential unit of a high-rise residential building or a hotel/motel guest room), ACMs must require the user to input: 1) the design BHP; 2) the design drive motor efficiency; and, 3) the design motor efficiency, all at peak design air flow rates. Exhaust fans that are manually controlled (such as bathroom fans) may not operate at design conditions and therefore must **not** be included in the fan system power demand calculations.

The reference method calculates the FPI for each fan system according to the following equation:

$$FPI = \frac{746}{CFM_s}\left[\frac{BHP_s}{h_{ds} \times h_{ms}} + \frac{BHP_r}{h_{dr} \times h_{mr}}\right]$$

where:

FPI	=	fan power index, [watts/cfm]
CFM_S	=	peak supply air flow rate, [ft^3/min]
BHP_S	=	brake horsepower of supply fan at CFM_S [hp]
o_{ds}	=	supply drive efficiency [unitless]
o_{ms}	=	supply motor efficiency [unitless]
BHP_r	=	brake horsepower of return fan at CFM_S [hp]
o_{dr}	=	return drive efficiency [unitless]
o_{mr}	=	return motor efficiency [unitless]

If the user does not input the design brake horsepower (BHP) and the peak supply air flow rate (cfm) for forced air systems, the ACM shall assume that no mechanical compliance will be performed and shall model the default mechanical system according to the rules in Section 2.4.2.26 (modeling default heating and cooling systems).

DOE Keyword: SUPPLY-KW
SUPPLY-DELTA-T
RETURN-KW
RETURN-DELTA-T

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: All ACMs must model proposed system fan power as documented in the plans and specifications for the building. The proposed design shall use the fan motor efficiency established in accordance with NEMA Standard MG1.

Modeling Rules for Reference Design (New): The reference method determines the standard design fan power as follows:

a) For systems 1, 2, and 5 with proposed FPI $\leq$ 0.80: The standard design FPI shall be the same as the proposed design.

b) For systems 1, 2 and 5 and proposed FPI > 0.80: The standard design FPI shall be 0.80.

c) For systems 3 and 4 and proposed FPI $\leq$ 1.25: The standard design FPI shall be the same as the proposed design.

d) For systems 3 and 4 and proposed FPI > 1.25: The standard design FPI shall be 1.25.

ACMs shall use the same BHP, peak supply flow rate, and drive efficiency as the proposed design. The reference method shall use the appropriate minimum nominal full-load motor efficiency from Table 2-8.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): All ACMs must model the existing system fan power according to the specifications of the existing system. The reference method shall use the full-load nominal efficiency of the existing motor as established in accordance with NEMA Standard MG1. If the efficiency of the existing motor is not available, ACMs shall use the appropriate minimum nominal full-load motor efficiency from Table 2-8.

2.4.2.23 Process Fan Power

Description: Portion of the total fan power exclusively used for air treatment or filtering systems. For each fan system used for air treatment or filtering, ACMs must adjust the fan power index according to the following equation:

$$\text{Adjusted Fan Power Index (FPI)} = \text{Total FPI} \times (1 - SP_a/SP_f)$$

where:

SP_a = Air pressure drop across air treatment or filtering system, and
SP_f = Total pressure drop across the fan system

Fans whose fan power exclusively serve as process fans must not be modeled for simulation.

2.4.2.24 Air Economizers

Description: The reference method is capable of simulating an economizer that: (1) modulates outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation.

The reference method will simulate at least two types of economizers and all ACMs must receive input for these two types of economizers:

1. *Integrated*. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. *Nonintegrated/fixed set point*. This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

DOE Keyword: ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT

Input Type: Default

Tradeoffs: Yes

Modeling Rules for The ACM shall allow the user to input either an *integrated* or *non-integrated*

Proposed Design: economizer as described above as it occurs in the construction documents. The ACM shall require the user to input the ODB set point.

Default: No Economizer

Modeling Rules for Reference Design (New): The standard design shall assume an *integrated* air economizer, available for cooling any time ODB < ~~75~~T_{limit}, on systems 1, 2, 3 and 4 (See ***Standard Design Systems Types***) when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm. T_{limit} shall be set to 75°F for climate zones 1, 2, 3, 5, 11, 13, 14, 15 & 16. T_{limit} shall be set to 70°F for climate zones 4, 6, 7, 8, 9, 10 & 12. The ACM shall not assume economizers on any system serving high-rise residential and hotel/motel guest room occupancies.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): All ACMs must model existing economizers as they occur in the existing building.

2.4.2.25 Sizing Requirements

Description: ACMs must determine outdoor weather design conditions from the user entry for building location which in turn is selected from a list of cities. The Commission can provide software for city selection which is linked to a database of outdoor design conditions. The outdoor design data determined from the building location is used for calculating design heating and cooling loads. In certain rural locations the user may enter a building location that is not the closest city with the explicit approval of the local enforcement agency. The same city must appear for all reports of building location and design weather data. The indoor design air temperature is based on the occupancy type using Table 2-4, 2-5, 2-6, or 2-7.

ACMs must perform design heating and cooling load calculations for each zone of the standard and proposed buildings. The design load methodology must be consistent with the ASHRAE Handbook, 1997, Fundamentals Volume, or with another method approved by the Executive Director.

The reference method uses the following assumptions for design loads:

- ***Fixed design assumptions by occupancy as listed in Tables 2-1 or 2-2.*** Different occupancy schedules are used by the reference method to determine design loads. For cooling loads, lights, equipment/receptacles, and people are at 100% of full load while the building is occupied. For heating loads, these internal gains are 0% of full load at all hours of the day. The HVAC equipment operational hours and thermostat settings schedules must be based on the selected occupancy type using the occupancy schedules shown in Table 2-4, 2-5, 2-6, or 2-7.

- ***Ventilation and process loads.*** See applicable sections on *ventilation and process loads.*

- ***Outdoor design temperatures for the building site location from ASHRAE publication SPCDX****: Climate Data for Region X, Arizona, California, Hawaii and Nevada, 1982*; latitude of building site location.

- ***Design temperatures, summer daily temperature swing and latitude***. The ACM user must either be able to select a city from a list which automatically retrieves the ASHRAE Region X Winter Median of Extremes temperature; and the Summer Dry-Bulb (0.5%) and Mean Coincident Wet-Bulb temperatures for the building site from a database; or the user must be able to enter the values mentioned above directly into the ACM. The ACM user must also enter the daily temperature range for the design cooling day and the latitude or have this value determined by city selection.

ACMs must calculate, for both the standard and proposed designs, heating and cooling loads and appropriate capacities for supply fans, cooling and heating equipment, hydronic pumps and heat rejection equipment as appropriate for the five standard design systems. All assumptions for heating and cooling equipment and fan system sizing are documented below.

2.4.2.25.1 Cooling Loads

Description: The reference method calculates cooling loads for each fan system using the following assumptions:

- Peak cooling design day profiles developed from *ASHRAE SPCDX: Climate Data for Region X, Arizona, California, Hawaii and Nevada, 1982* design weather data for the city in which the building will be built. These profiles must be developed using a method similar to the design day method of the reference computer program.

- All window interior and user-operated shading devices are ignored.

- Internal gains from occupants and receptacle loads are fixed at 100% of the values listed in Tables 2-1 or 2-2 while the building is occupied.

- Indoor dry-bulb temperatures are specified according to Tables 2-4, 2-5, 2-6, or 2-7, however, the ACM must be able to calculate the indoor wet-bulb temperature using the occupancy information and the cooling coil characteristics.

- Outdoor design temperatures equal to those listed in the Summer Design Dry Bulb 0.5% and the Summer Design Wet-Bulb 0.5% columns of ASHRAE publication SPCDX are used. For cooling tower design, temperatures listed in the Summer Design Wet-Bulb 0.5% columns must be used.

Modeling Rules for Proposed Design: The reference method calculates the proposed design cooling load using the same assumptions used by the mechanical system designer, including all proposed lighting, ventilation and process load at a constant 100% of the levels documented in the plans and specifications for the building. That is internal loads are all at 100% of full load for the duration of the cooling load calculation.

Modeling Rules for Reference Design (All): The reference method calculates the standard design load calculations with the following assumptions:

- Lighting levels fixed according to Table 2-1 or 2-2 unless *tailored lighting* documentation and forms are submitted and *tailored lighting* levels are input by the user, in which case the *tailored lighting* level is assumed. A non-zero *tailored lighting* input is an exceptional condition requiring approved or concurrently-submitted prescriptive lighting forms and documentation and special verification by the local enforcement agency.

- Ventilation levels fixed according to Tables 2-1 or 2-2 unless *tailored ventilation* rates are justified and input by the user, in which case the *tailored ventilation* level is assumed. A non-zero *tailored ventilation* input is an exceptional condition requiring written justification by the applicant and special verification by the local enforcement agency.

- Process loads are assumed to be zero unless the locations and types of the equipment producing the process energy are specified on the plans and specifications of the building. Process loads are an exceptional condition requiring written justification by the applicant and special verification by the local enforcement agency.

2.4.2.25.2 Heating Loads

Description: The reference method calculates heating loads for each fan system using the following assumptions:

- Indoor design temperatures according to Tables 2-5 or 2-6.

- No direct solar heat gains.

- All internal gains -- occupants, receptacle loads, other loads (such as pickup load) and lighting levels shall be assumed to be 0% of user input, default and fixed values.

- Indoor design temperatures according to Tables 2-5 or 2-6.

- Outdoor design temperatures equal to those listed in the Winter Median of Extremes column of ASHRAE publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982.

2.4.2.25.3 Sizing Procedure for Systems 1, 3, 4, and 5

Modeling Rules for Proposed Design:

1. Calculate proposed fan air flow requirements, cfm_{pc}, based on the design supply air temperature input by the user. The calculated proposed fan air flow requirement is the larger of the heating and cooling air flow requirements, but no lower than 0.4 cfm/sf overall.

Note: In the text that follows regarding the "design procedure" or "sizing procedure" subscripts are used for a variety of variables. In the first subscript position subscripts symbols mean:

p = proposed - for the proposed building or design
s = standard - for the standard or reference design

In the second subscript position subscript symbols are used:

c = calculation - for design calculation or sizing calculation
s = simulation - for the compliance simulation
i = input - for user input

In some instances, nom is added after the subscripts to indicate the nominal value of a variable requiring further adjustments.

For the sizing ratio, R, subscripts are used:

f = fans
c = cooling
h = heating

Calculate, R_f, the ratio of the actual proposed design fan air flow, cfm_{pi} and the calculated fan air flow requirement, cfm_{pc}, and determine the standard design fan sizing factor, F, and the proposed modeled supply air flow rate, cfm_{ps}, as follows:

if $R_f \geq 1.3$	$F = 1.3$	$cfm_{ps} = cfm_{pi}$
if $1.0 < R_f < 1.3$	$F = R_f$	$cfm_{ps} = cfm_{pi}$
if $R_f \leq 1.0$	$F = 1.0$	$cfm_{ps} = cfm_{pc}$

Adjust all zone supply air rates and supply air rates for groups of zones according to the procedure described above.

2. Calculate system coil loads by adjusting the proposed design calculated cooling loads for fan heat and ventilation loads.

3. Reheat coil sizes are as input by the user for interior zones. Reheat with series for perimeter zones are as input by the user but no smaller than 120% of the peak heating load assuming minimum supply air temperature. All VAV minimum positions are as input by the user but no smaller than the minimum ventilation quantity.

4. Calculate total individual cooling plant loads, $CCAP_{pc}$, as the sum of all calculated coil loads served by individual plants (eg. direct expansion unit, chiller, etc.).

   Calculate, R_c, the ratio of the input proposed total plant cooling capacity, $CCAP_{pi}$, to the proposed calculated total cooling capacity, $CCAP_{pc}$, and determine the standard design cooling sizing factor, C, and the proposed nominal modeled total cooling capacity, $CCAP_{psnom}$, as follows:

if $R_c \geq 1.21$ C = 1.21 $CCAP_{psnom} = CCAP_{pi}$
if $1.0 < R_c < 1.21$ $C = R_c$ $CCAP_{psnom} = CCAP_{pi}$
if $R_c \leq 1.0$ C = 1.0 $CCAP_{psnom} = CCAP_{pc}$

$CCAP_{ps}$ is determined from $CCAP_{psnom}$ by adjusting for fan generated heat:

$$CCAP_{ps} = CCAP_{psnom} + 1.08(CFM_{ps} - CFM_{pc}) \times \text{Fan } T_p$$

5. Calculate individual heating plant loads, $HCAP_{pc}$, as the sum of all calculated coil loads served by individual plants (eg. boiler, furnace, etc.).

   a) For system 1, the calculated proposed system heating capacity, $HCAP_{pc}$ is the larger of the actual fan cfm x 25 and the calculated steady state heating. Calculate, R_h, the ratio of the input proposed plant heating capacity, $HCAP_{pi}$, to the proposed calculated heating capacity, $HCAP_{pc}$, and determine the standard design heating sizing factor, H, and the proposed modeled heating capacity, $HCAP_{ps}$, as follows:

   if $R_h \geq 1.43$ H = 1.43 $HCAP_{ps} = HCAP_{pi}$
   if $1.2 < R_h < 1.43$ $H = R_h$ $HCAP_{ps} = HCAP_{pi}$
   if $R_h \leq 1.2$ H = 1.2 $HCAP_{ps} = 1.2 \times HCAP_{pc}$

   b) For systems 3, 4 and 5, calculate, R_h, the ratio of the input proposed plant heating capacity, $HCAP_{pi}$, to the input calculated heating capacity, $HCAP_{pc}$, and determine the standard design heating sizing factor, H, and the proposed modeled heating capacity, $HCAP_{ps}$, as follows:

   if $R_h \geq 1.43$ H = 1.43 $HCAP_{ps} = HCAP_{pi}$
   if $1.2 < R_h < 1.43$ $H = R_h$ $HCAP_{ps} = HCAP_{pi}$
   if $R_h \leq 1.2$ H = 1.2 $HCAP_{ps} = 1.2 \times HCAP_{pc}$

Modeling Rules for Reference Design (All):

1. Load calculations are performed for the standard building. Total system fan supply air flows are calculated using the same supply air temperatures used for the proposed design, except limited to the ranges listed in the standard design system inputs in Figures 2-2a through 2-2d, and multiplied by the standard design sizing factor, F, determined in the proposed design sizing procedure.

2. Supply air quantities for each zone of multiple zone systems are determined by calculated zone loads, adjusted so that the block load adds up to the fan cfm.

3. Reheat coil sizes are determined with minimum VAV box positions of 0.8 for interior zones and 0.5 for perimeter zones on interior included reheat coils are only to the standard design if they have been input for the proposed design. Standard design VAV characteristics are determined as follows:

Air flow rates for interior zones (only those without exterior walls) are further oversized by 33%. Minimum VAV settings for interior VAV zones are set to meet the larger of minimum ventilation requirements, 0.4 cfm/sf or 30% of the zone peak supply air requirements. Reheat is added to meet ventilation loads only if input for the proposed design.

Minimum volume settings for exterior VAV zones are set to the larger of 0.4 cfm/sf or 30% of the zone peak supply air requirements.

4. Standard system coil loads are calculated based on calculated zone loads adjusted for fan heat and ventilation loads, then adjusted again for piping loads (for hydronic systems only). Standard system plant capacities are determined by multiplying adjusted coil loads by the standard design sizing factors, C and H, determined in the proposed design sizing procedure.

2.4.2.25.4 Sizing Procedure for System 2

Modeling Rules for Proposed Design:

1. Calculate proposed fan air flow requirements, cfm_{pc}, based on the design supply air temperature input by the user or the default supply air temperature listed in the system description in Figure 2-2a. The calculated proposed fan air flow requirement is the larger of the heating and cooling air flow requirements, but no lower than 0.4 cfm/sf overall.

   Calculate, R_f, the ratio of the actual proposed design fan air flow, cfm_{pi} and the calculated fan air flow requirement, cfm_{pc}, and determine the standard design fan sizing factor, F, and the proposed modeled supply air flow rate, cfm_{ps}, as follows:

if $R_f \geq 1.3$	$F = 1.3$	$cfm_{ps} = cfm_{pi}$
if $1.0 < R_f < 1.3$	$F = R_f$	$cfm_{ps} = cfm_{pi}$
if $R_f \leq 1.0$	$F = 1.0$	$cfm_{ps} = cfm_{pc}$

   Adjust all zone supply air rates and supply air rates for groups of zones according to the procedure described above.

2. Calculate system coil loads by adjusting the proposed design calculated cooling loads for fan heat and ventilation loads.

3. Calculate, R_c, the ratio of the input proposed plant cooling capacity, $CCAP_{pi}$, to the same calculated capacity, $CCAP_{pc}$, and determine the standard design cooling sizing factor, C, and the proposed modeled cooling capacity, $CCAP_{ps}$, as follows:

if $R_c \geq 1.21$	$C = 1.21$	$CCAP_{ps} = CCAP_{pi}$
if $1.0 < R_c < 1.21$	$C = R_c$	$CCAP_{ps} = CCAP_{pi}$
if $R_c \leq 1.0$	$C = 1.0$	$CCAP_{ps} = CCAP_{pc}$

4. Calculate the amount of electric resistance heat, $HCAP_{pelec}$, by comparing

the user input heating capacity at design conditions, $HCAP_{pdesign}$, to the actual heating load and using the following equations:

$$HCAP_{pdesign} = HP \times HCAP_{pi}$$
$$HLOAD_{pdesign} = HP \times HCAP_{sc}$$
$$HCAP_{pelec} = 1.43 \times HLOAD_{pdesign} - HCAP_{pdesign}$$

5. If the user does not input design heat pump heating capacity, calculate $HCAP_{elec}$ according to the following procedure:

   a) Calculate the heat pump design load factor, HP, from equation 2.4.11.

   b) Calculate $HCAP_{pdesign}$ by multiplying the rated heat pump heating capacity, input by the user, by HP.

   c) Use the equation under step 4 to calculate $HCAP_{elec}$.

Modeling Rules for Reference Design (All):

1. Load calculations are performed for the standard building. Total system fan supply air flows are calculated using the standard design cooling load and the same supply air temperatures used for the proposed design, except limited to the ranges listed in the standard design system inputs in Figure 2-2a, and multiplied by the standard design fan sizing factor, F, determined in the proposed design sizing procedure.

2. Standard system coil loads are calculated based on calculated zone loads adjusted for fan heat and ventilation loads. Standard system cooling capacity is determined by multiplying adjusted coil loads by the standard design cooling sizing factors, C, determined in Step 3 of the proposed design sizing procedure, unless Step 4 below applies.

3. Standard design heating capacity, $HCAP_{ss}$, is determined from the following procedure:

   a) $CCAP_{ss} = C \times (CCAP_{sc} + 1.08[CFMss\text{-}CFMsc] \times Fan\ \ T_s)$
   and

   $$SCAP_{ss} = C \times SCAP_{sc}$$

   $$HCAP_{ss} = CCAP_{ss}$$

   b) Calculate the heat pump design load factor, HP, from the following equation:

   $$HP = 0.25367141 + 0.01043512\ K + 0.00018606\ K^2 - 0.00000149\ K^3 \qquad \textbf{Equation 2.4.11}$$

   where

   $$K = T_{outside}$$

c) Calculate the design heating capacity, $HCAP_{sdesign}$, by multiplying the rated heat pump heating capacity, input by the user, by HP.

$$HCAP_{sdesign} = HP \times HCAP_{pi}$$

$$HLOAD_{sdesign} = HP \times HCAP_{sc}$$

d) $HCAP_{sdesign}$ is adjusted to be the larger of $HCAP_{sdesign}$, and 75% of the actual design heating load adjusted for fan power and ventilation loads, $HLOAD_{sdesign}$, or

$$HCAP_{sdesign} = \text{MAXIMUM} (HCAP_{sdesign}, 0.75 \times HLOAD_{sdesign})$$

e) The electric heating capacity for the standard design is thus determined:

$$HCAP_{selec} = 1.43 \times HLOAD_{sdesign} - HCAP_{sdesign}$$

f) If $HCAP_{sdesign}$ is determined from $0.75 \times HLOAD_{sdesign}$, then the modeled standard design heat pump heating capacity, $HCAP_{ss}$, is determined from the following equation:

$$HCAP_{ss} = HLOAD_{sdesign} / HP$$

$$CCAP_{ss} = HCAP_{ss}$$

2.4.2.26 Modeling Default Heating and Cooling Systems

Description: ACMs shall model the proper default heating and cooling systems when the user indicates, with the required ACM input, one of the following conditions for the building:

1. *Mechanical compliance not performed*. When the user indicates that no mechanical compliance will be performed, the ACM must automatically model the default heating and cooling systems identical to the standard systems defined in Section 2.4.2.4 (Standard Design Systems). The ACM shall require the user to provide the information needed to determine the proper default system type.

2. *Mechanical compliance performed with no heating installed*. When the user indicates that mechanical compliance will be performed, but the entire project or portions of the space have no installed heating or are heated by an existing heating system, the ACM must default to a heating system identical to the standard heating system defined in Section 2.4.2.4 (Standard Design Systems) for the space(s) with no installed heating or heated by an existing system. The ACM shall require the user to provide the information needed to determine the proper default system type.

3. *Mechanical compliance performed with no cooling installed*. When the user indicates with the required ACM input that mechanical compliance will be performed, but the entire project or portions of the space have no installed cooling or are cooled by an existing cooling system, the ACM must default to a cooling system identical to the standard cooling system defined in Section 2.4.2.4 (Standard Design Systems) for the space(s) with no installed cooling or cooled by an existing system. The ACM shall require the user to provide the information needed to determine the proper default system type.

The heating fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

DOE Keyword: SYSTEM-TYPE

Input Type: Prescribed

Tradeoffs: N/A

Modeling Rules for Proposed Design: The proposed design systems shall be determined as follows:

1. *Mechanical compliance not performed*. ACMs shall automatically size and model the default heating and cooling systems and adjust the heating by the standard design sizing factor of 1.2. ACMs shall select the proper mechanical system based on the building type and whether the permitted space is single zone (the conditioned floor area is less than 2500 ft^2) or multiple zone (the conditioned floor area is 2500 ft^2 or greater). See Section 4.3.3.1 (Thermal Zones) for guidelines for zoning a building. The heating fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

   ACMs **must** report the default heating and cooling energy use on PERF-1 and indicate that mechanical compliance was not performed. ACMs **must not** print any Mechanical forms.

2. *Mechanical compliance performed with no heating installed*. ACMs shall automatically size and model the default heating system for the entire project or portions of the space which have no installed heating or use an existing system and adjust the capacity by the standard design sizing factor of 1.2. ACMs shall select the type of heating system based on the building type and whether the permitted space is single zone or multiple zone. The heating fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

   ACMs **must** print all applicable mechanical forms and report the heating energy use for the entire project. ACMs **must** report "No Heating Installed" for zones with no installed heating system and for zones using the existing heating system.

3. *Mechanical compliance performed with no cooling installed*. ACMs shall automatically size and model the default cooling system for the entire project or portions of the space which have no installed cooling or use an existing cooling system. ACMs shall select the type of heating system based on the building type and whether the permitted space is single zone or multiple zone.

The heading fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be “other”.

ACMs **must** print all applicable mechanical forms and report the cooling energy use for the entire project. ACMs **must** report “No Cooling Installed” for zones with no installed cooling system and for zones using the existing cooling system.

Proposed design supply air rates and heating capacity shall be determined according to procedures in Section 2.4.2.25 (Sizing Requirements) for the appropriate system type. Fan power shall be determined using 0.365 watts per cfm of supply air rate for the cooling system. The rate of supply air (in cfm) must meet the building’s minimum ventilation requirements.

For occupancies other than the residential units of high-rise residential buildings and hotel/motel guest rooms, this default proposed cooling system shall also have an integrated dry-bulb economizer as specified in this section, regardless of the capacity.

Modeling Rules for Reference Design (All): ACMs shall determine the reference design systems as follows:

1. *Mechanical compliance not performed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems **for the entire project** using Section 2.4.2.4 (Standard Design Systems). ACMs shall use the standard design sizing factor of 1.2 for heating.

2. *Mechanical compliance performed with no heating installed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems **for the entire project** using Section 2.4.2.4 (Standard Design Systems). ACMs must adjust the heating capacity by the standard design sizing factor of 1.2.

3. *Mechanical compliance performed with no cooling installed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems **for the entire project** using Section 2.4.2.4 (Standard Design Systems).

Standard design supply air rates, heating, and cooling capacity shall be determined according to procedures in Section 2.4.2.25 (Sizing Requirements) for the appropriate system type. Fan power shall be determined using 0.365 watts per cfm of supply air rate for the cooling system. The rate of supply air (in cfm) must meet the building’s minimum ventilation requirements.

For occupancies other than the residential units of high-rise residential buildings and hotel/motel guest rooms this default standard cooling system shall also have an integrated dry-bulb economizer as specified in this section, regardless of the HVAC system fan volume or cooling capacity.

2.4.2.27 System Supply Air Temperature Control

Description: ACMs must be capable of modeling two control strategies, or reset strategies, for supply air temperature for any system compared to standard design systems 3 and 4. ACMs must: (1) require the user to specify the control strategy used for controlling supply air temperature; and , (2) allow the user to enter the design cooling supply air temperature. Each of these strategies is described below.

- *Constant*. Cooling supply air temperature is controlled to a fixed set point whenever cooling is required.
- *Outdoor Air Reset*. Cooling supply air temperature resets upward during cool weather to reduce zone reheat losses. The ACM must require the user to enter the reset schedule.

NOTE: Modeling dual duct systems in the proposed design requires the user to enter the heating supply air temperature control strategy as well. Refer to the Optional Systems and Plant Capabilities.

DOE Keyword: HEAT-CONTROL
COOL-CONTROL
DAY-RESET-SCH

Input Type: Default

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The reference method determines the supply air temperature control of the proposed design as input by the user according to the plans and specifications for the building. ACMs shall use the following schedule for the outdoor air reset:

```
SUPP-AIR-SCH    = DAY-RESET-SCH
SUPPLY-HI       = [SUPPLY-LO + 5]
SUPPLY-LO  = [greater of SAT and 50]
OUTSIDE-HI = [SUPPLY-HI]
OUTSIDE-LO      = [SUPPLY-LO]  ..

SUPP-AIR-RESET = RESET-SCHEDULE THRU DEC 31,
      (ALL)     SUPP-AIR-SCH  ..
```

In the absence of the user input, ACMs shall use the Outdoor Air Reset control strategy for the proposed building.

Default: Outdoor Air Reset

Modeling Rules for Reference Design (All): The reference method shall use the same supply air temperature control strategy and schedule as the proposed design.

2.4.2.28 Zone Ventilation Air

Description: The reference method models mechanical supply of outdoor ventilation air as part of simulation of any fan system. The ventilation rate for a fan system is the sum of all ventilation requirements for all zones served by the same fan system.

ACMs must allow the user to: 1) enter the ventilation rate for each zone; and, 2) identify the user input ventilation rate as a *tailored ventilation* rate. When *tailored ventilation* rates are entered for any zone, an ACM shall output on compliance forms that *tailored ventilation* rates have been used for compliance and that a Tailored Ventilation worksheet, and the reasons for different ventilation rates, must be provided as part of the compliance documentation. Tailored ventilation inputs are designed to allow special HVAC applications to comply, but to be used they must correspond to specific needs and the particular design and the plans and specifications used to meet those needs.

The reference method determines the minimum building ventilation rate by summing the ventilation rates for all zones determined from Table 2-1 or Table 2-2 as well as zones with *justified tailored ventilation rates*, input by the user.

DOE Keyword: OUTSIDE-AIR-CFM
MIN-OUTSIDE-AIR

Input Type: Default

Tradeoffs: N/A

Modeling Rules for Proposed Design: The reference method determines the proposed design zone ventilation rate as follows:

1. If no ventilation rate has been entered by the user, the ACM shall use values from Table 2-1 or 2-2 for the applicable occupancy as the zone ventilation rate for the proposed design.

2. If the zone ventilation rate has been entered by the user, the ACM shall use this value as the zone ventilation rate for the proposed design.

This total must not be less than the minimum ventilation rate calculated above. **The ACM must default to the minimum ventilation rate if the proposed ventilation rate, input by the user, is less than the minimum ventilation rate.**

Default: Ventilation rates from Table 2-1 or 2-2.

Modeling Rules for Reference Design (All): The reference method determines the standard design zone ventilation rate as follows:

1. If no *tailored ventilation* rate has been entered, the ACM shall use values from Table 2-1 or 2-2 for the applicable occupancy as the zone ventilation rate for the standard design.

2. If a *tailored ventilation* rate has been entered, the ACM shall assume the tailored value as the zone ventilation rate for the standard design.

2.4.2.29 Zone Terminal Controls

Description: ACMs must be capable of modeling zone terminal controls with the following features:

- *Variable air volume (VAV).* Zone loads are met by varying amount of supply air to the zone.

- *Minimum box position*. The minimum supply air quantity of a VAV zone terminal control must be set as a fixed amount per conditioned square foot or as a percent of peak supply air.

- *(Re)heating Coil*. ACMs must be capable of modeling heating coils (hot water or electric) in zone terminal units. ACMs may allow users to choose whether or not to model heating coils.

- *Hydronic heating*. The ACM must be able to model hydronic (hot water) zone heating.

- *Electric Heating*. The ACM must be able to model electric resistance zone heating.

ACMs must require the user to specify the above criteria for any zone terminal controls of the proposed system.

DOE Keyword: MIN-CFM-RATIO
ZONE-HEAT-SOURCE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The reference method models any zone terminal controls for the proposed design as input by the user according to the plans and specifications for the building. **All ACMs that explicitly model variable air volume systems must not allow any minimum box position to be smaller than the air flow per square foot needed to meet the minimum occupancy ventilation rate.**

Modeling Rules for Reference Design (New & Altered Existing): For systems 3 and 4, the ACM must model zone terminal controls for the standard design with the following features:

- Variable volume cooling and fixed volume heating

- Minimum box position set equal to the larger of:

  (a) 30% of the peak supply volume for the zone; or
  (b) The air flow needed to meet the minimum zone ventilation rate; or
  (c) 0.4 cfm per square foot of conditioned floor area of the zone.

- Hydronic heating.

Modeling Rules for Reference Design (Existing Unchanged): The reference method models any zone terminal control for the existing design as it occurs in the existing system.

2.4.2.30 Pump Energy

Description: The reference method models energy use of pumping systems for hot water, chilled water and condenser water systems (cooling towers), accounting for energy use of pumps and additional cooling energy associated with pump energy rejected to the water stream.

DOE Keyword: CCIRC-MOTOR-EFF
CCIRC-IMPELLER-EFF
CCIRC-HEAD
CCIRC-DESIGN-T-DROP
HCIRC-MOTOR-EFF
HCIRC-IMPELLER-EFF
HCIRC-HEAD
HCIRC-DESIGN-T-DROP
TWR-MOTOR-EFF
TWR-IMPELLER-EFF
TWR-PUMP-HEAD
TWR-RANGE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The reference method calculates proposed design pump energy using the following inputs and procedures:

- Hot Water Circulation Loop Pump

  a) Impeller Efficiency 67%
  b) Motor Efficiency Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.4.2.17)

$$HCIRC-MOTOR-EFF = \frac{\sum_{i=1}^{n}(MEFF_{hwp\_i} \times HP_{hwp\_i})}{\sum_{i=1}^{n} HP_{hwp\_i}}$$

where

$MEFF_{hwp\_i}$ = Hot water pump motor efficiency
HP_{hwp_i} = Hot water pump motor nameplate HP
n = Number of hot water pump motors

  c) Motor Horsepower As Designed
  d) Flow Rate As Designed (in GPM)
  e) Temperature Drop =Design Boiler Capacity (Btu)/(500×GPM) (in ^{o}F)
  f) Design Head As Designed with a maximum of 100 feet of water.
  g) Pump Control As Designed

- Chilled Water Circulation Loop Pump

a) Impeller Efficiency 72%
b) Motor Efficiency Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.4.2.17)

$$CCIRC-MOTOR-EFF=\frac{\sum_{i=1}^{n}(MEFF_{chwp\_i}\times HP_{chwp\_i})}{\sum_{i=1}^{n}HP_{chwp\_i}}$$

where

$MEFF_{chwp\_i}$ = Chilled water pump motor efficiency
HP_{chwp_i} = Chilled water pump motor nameplate HP
n = Number of chilled water pump motors

c) Motor Horsepower As Designed
d) Flow Rate As Designed (in GPM)
e) Temperature Drop Calculated as follows (in ^oF)

$$CCIRC-DESIGN-T-DROP=\frac{\sum_{i=1}^{n}(Q_{des\_i})\times 12}{\sum_{i=1}^{n}(GPM_{evap\_i})\times 0.5}$$

where

Q_{des_i} = Chiller design capacity in tons
GPM_{evap_i} = Flow rate in the evaporator in GPM
n = Number of chillers

f) Design Temperature As Designed (in ^oF)
g) Design Head Minimum (100, $\Delta H_{chwsyspiping}$) in feet of water

$$\Delta H_{chwsyspiping}=\Delta H_{chwsys}-\frac{\sum_{i=1}^{n}(GPM_{evap\_i}\times\Delta H_{evap\_i})}{\sum_{i=1}^{n}GPM_{evap\_i}}$$

where

$\Delta H_{chwsyspiping}$ = Chilled water piping system head
ΔH_{chwsys} = Chilled water system head
GPM_{evap_i} = Evaporator flow (in GPM)
ΔH_{evap_i} = Evaporator bundle pressure drop (in feet of water)

n = Number of evaporators in the system

h) Pump Control As Designed

- Condenser Water Circulation Loop Pump

a) Impeller Efficiency 67%
b) Motor Efficiency Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.4.2.17)

$$TWR - MOTOR - EFF = \frac{\sum_{i=1}^{n}(MEFF_{cwp\_i} \times HP_{cwp\_i})}{\sum_{i=1}^{n} HP_{cwp\_i}}$$

where

$MEFF_{cwp\_i}$ = Condenser water pump motor efficiency
HP_{cwp_i} = Condenser water pump motor nameplate HP
n = Number of condenser water pump motors

c) Motor Horsepower As Designed
d) Flow Rate As Designed (in GPM)
e) Range As Designed (in ^{o}F)
f) Design Head Minimum(80, ΔH_{cws}) in feet of water

$$\Delta H_{cws} = \Delta H_{cwsys} + \frac{\sum_{i=1}^{n}(GPM_{evap\_i} \times \Delta H_{evap\_i})}{\sum_{i=1}^{m} GPM_{cond\_i}}$$

where

ΔH_{cwsys} = Condenser water system head
ΔH_{evap_i} = Evaporator bundle pressure drop (in feet of water)
ΔH_{cws} = Proposed Condenser water system head
GPM_{evap_i} = Evaporator flow (in GPM)
GPM_{cond_i} = Condenser flow (in GPM)
n = Number of evaporators in the system
m = Number of condensers in the system

g) Cooling Tower Height As Designed
h) Pump Control As Designed

Modeling Rules for Reference Design (New): The reference method calculates standard design pump energy using the following inputs and procedures:

- Hot Water Circulation Loop Pump

a)	Impeller Efficiency	67%
b)	Motor Efficiency	Standard Motor Efficiency from Table 2-8
c)	Motor Horsepower	Same as the proposed design
d)	Flow Rate (in GPM)	Calculated from Standard Boiler Capacity = Boiler Capacity / 15000
e)	Temperature Drop	30 ^oF
f)	Standard Head	Same as proposed up to 100 feet of water
g)	Pump Control	Fixed Speed

- Chilled Water Circulation Loop Pump

a)	Impeller Efficiency	72%
b)	Motor Efficiency	Standard Motor Efficiency from Table 2-8
c)	Motor Horsepower	Same as the proposed design
d)	Flow Rate (in GPM)	Calculated from Standard Chiller Capacity GPM = tons $\times$ 2.0
e)	Temperature Drop	12 ^oF
f)	Design Temperature	44 ^oF
g)	Standard Head	Same as proposed design up to 100 feet of water
h)	Pump Control	Fixed Speed

- Condenser Water Circulation Loop Pump

a)	Impeller Efficiency	67%
b)	Motor Efficiency	Standard Motor Efficiency from Table 2-8
c)	Motor Horsepower	Same as the proposed design
d)	Range	10 ^oF
e)	Flow Rate (in GPM)	Calculated from Standard Chiller Capacity GPM = tons $\times$ (1 + 1/COP) $\times$ 2.4
f)	Standard Head	Minimum (80 , ΔH_{cws}) in feet of water

$$\Delta H_{cws} = \frac{\Delta H_{cwsyspiping}}{Multiplier} + 20 + \frac{\sum_{i=1}^{n} (GPM_{evap\_i} \times 20)}{\sum_{i=1}^{m} GPM_{cond\_i}}$$

where

$$\Delta H_{cwsyspiping} = \Delta H_{cwsys} - \frac{\sum_{i=1}^{m} (GPM_{cond\_i} \times \Delta H_{cond\_i})}{\sum_{i=1}^{m} GPM_{cond\_i}}$$

$\Delta H_{cwsyspiping}$	= Condenser water piping system head
ΔH_{cwsys}	= Condenser water system head
ΔH_{cond_i}	= Condenser bundle pressure drop (in feet of water)
ΔH_{cws}	= Standard Condenser water system head
GPM_{evap_i}	= Evaporator flow (in GPM)

GPM_{cond_i} = Condenser flow (in GPM)
Multiplier = A multiplier From Table 2-9 for adjusting the condenser water piping system head based on pipe size and flow at connection to the cooling tower.
n = Number of evaporators in the system
m = Number of condensers in the system

g) Pump Control Fixed Speed

Table 2-9: Pipe Head Multipliers Based on Pipe Size and Flow at Connection to the Cooling Tower

Proposed Flow		*Normal Size*		*Undersize down to*		*Oversized up to*	
From (GPM)	*To (GPM)*	*Pipe Size (inch)*	*Multiplier*	*Pipe Size (inch)*	*Multiplier*	*Pipe Size (inch)*	*Multiplier*
1	35	1.50	1.00	1.25	2.00	2.00	0.31
36	74	2.00	1.00	1.50	3.00	2.50	0.38
75	107	2.50	1.00	2.00	2.25	3.00	0.35
108	180	3.00	1.00	2.50	2.75	4.00	0.25
181	355	4.00	1.00	3.00	3.75	5.00	0.30
356	580	5.00	1.00	4.00	3.00	6.00	0.38
581	880	6.00	1.00	5.00	2.50	8.00	0.25
881	1,600	8.00	1.00	6.00	3.75	10.00	0.30
1,601	2,500	10.00	1.00	8.00	3.00	12.00	0.38
2,501	3,700	12.00	1.00	10.00	2.25	14.00	0.63
3,701	4,500	14.00	1.00	12.00	1.50	16.00	0.50
4,501	6,500	16.00	1.00	14.00	1.88	18.00	0.55
6,501	9,000	18.00	1.00	16.00	1.75	20.00	0.53
9,001	12,000	20.00	1.00	18.00	1.75	24.00	0.43
12,001	16,000	24.00	1.00	20.00	1.75	30.00	0.50
16,001	20,000	30.00	1.00	24.00	1.75	36.00	0.50
20,001	30,000	36.00	1.00	30.00	1.75	N/A	1.0
30,001	>30,001	Any Size	1.00	N/A	1.0	N/A	1.0

Default: Hot water loop design head = 75 feet of water
Chilled water loop design head = 75 feet of water
Condenser water loop design head = 60 feet of water

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACM shall use the information from the existing pumping systems for the reference design. If these information are not available, ACMs shall use the above Standard Design values.

2.4.2.31 Chiller Characteristics

Description: The ACM chiller model must, at a minimum, incorporate the following characteristics:

- *Minimum Ratio:* The minimum capacity for a chiller below which it cycles.
- *Electrical Input Ratio:* Efficiency of the chiller at rated conditions. It is the ratio of the electrical power input to the chiller to the nominal capacity of the chiller.
- *Condenser Type:* It specifies whether the condenser is air-cooled or water-cooled.
- *GPM perTon:* The ratio of cooling tower water flow in GPM to chiller capacity in tons.

DOE Keyword: SIZE
MIN-RATIO
EIR
*-COND-TYPE
COMP-TO-TWR-WTR

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model chiller characteristics as follows:

- SIZE: The chiller size shall be calculated as follows

$$SIZE = \frac{Q_{des\_i} \times 0.012}{CAPFT(t_{chws\_des}, t_{cws\_des})}$$

where

Q_{des_i} = Chiller design capacity (in tons) at reference conditions
t_{chws_des} = Chilled water supply temperature at design conditions
t_{cws_des} = Condenser water supply temperature at design conditions
CAPFT() = Capacity performance curve (see 2.4.2.33)

- ***Minimum Ratio:*** For chillers with customized curves, ACMs shall calculate the *minimum ratio* using the part-load data by

$$MIN-RATIO = \frac{Q_{des\_i}}{\text{Minimum}\left(\left[Q_{pload\_i1}, Q_{pload\_i2}, \ldots, Q_{pload\_ij}\right]\right)}$$

where

Q_{pload_ij} = Chiller part-load performance data, Capacity in tons
Q_{des_i} = Chiller design capacity (in tons)

The default *minimum ratio* values are shown in the Table below.

Chiller Type **Default Unloading Ratio**

Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%

- ***Electrical Input Ratio***: ACMs shall calculate the Electrical Input Ratio (EIR) for chillers with customized performance curves from the user input data.

$$E-I-R=\frac{P_{des\_i}\times 3.413}{Q_{des\_i}\times EIRFT\left(t_{chws\_des},t_{cws\_des}\right)\times EIRFPLR(1.0)\times 12.0}$$

$$\cancel{E-I-R=\frac{P_{des\_i}\times 3.413}{Q_{des\_i}\times 12.0}}$$

where

P_{des_i} = Chiller design input power at design conditions t_{chws_des} and t_{cws_des} (in kW)

Q_{des_i} = Chiller design capacity at design conditions t_{chws_des} and t_{cws_des} (in tons)

EIRFT()= Efficiency performance curve (see 2.4.2.33)
EIRFPLR()= Efficiency performance curve (see 2.4.2.33)

For other chillers, ACMs shall calculate the EIR using

$$\cancel{E-I-R=\frac{1}{COP}}$$

$$E-I-R=\frac{1}{COP\times EIRFT(44,85)\times EIRFPLR(1.0)}$$

where

COP = Coefficient of Performance
EIRFT()= Efficiency performance curve (see 2.4.2.33)
EIRFPLR()= Efficiency performance curve (see 2.4.2.33)

- ***Condenser Type***: ACMs shall require the user to input whether the chiller is air-cooled or water-cooled.

- ***GPM per Ton***: For water-cooled chillers with customized performance curves, ACMs shall determine the condenser water flow as a ratio of condenser water flow rate (GPM) to rated chiller capacity (tons) using the following equation.

$$COMP-TO-TWR-WTR=\frac{\sum_{i=1}^{n}GPM_{cond\_i}}{\sum_{i=1}^{m}Q_{des\_i}}$$

where

GPM_{cond_i} = Condenser flow rate (in GPM)
Q_{des_i} = Chiller design capacity (in tons)
n = Number of condensers
m = Number of chillers

For default water-cooled chillers, ACMs shall determine the condenser water flow as follows.

$$COMP-TO-TWR-WTR=\left[1+\frac{1}{\frac{\sum_{i=1}^{n}(COP_i\times SIZE_i)}{\sum_{i=1}^{n}SIZE_i}}\right]\times 2.4$$

where

COP_i = Coefficient of performance for chiller i

$$SIZE_i=\frac{Q_{des\_i}\times 12{,}000}{1{,}000{,}000}$$

n = Number of chillers

Modeling Rules for Reference Design (New & Altered Existing): ACMs shall model chiller characteristics for the reference design as follows:

- SIZE: The chiller size shall be calculated as follows

$$SIZE=\frac{Q_i\times 0.012}{CAPFT(44,85)}$$

where

Q_i = Chiller capacity (in tons) at ARI reference conditions
CAPFT()= Capacity performance curve (see 2.4.2.33)

- ***Minimum Ratio:*** ACMs shall calculate the *minimum ratio* default values are shown in the Table below.

Chiller Type	**Default Unloading Ratio**
Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%

- ***Electrical Input Ratio***: ACMs shall calculate the Electrical Input Ratio (EIR) for the reference design using

$$\cancel{E-I-R=\frac{1}{COP}}$$

$$E-I-R=\frac{1}{COP\times EIRFT(44,85)\times EIRFPLR(1.0)}$$

where

COP = Coefficient of Performance
EIRFT()= Efficiency performance curve (see 2.4.2.33)
EIRFPLR()= Efficiency performance curve (see 2.4.2.33)

- ***Condenser Type***: ACMs shall model water-cooled condenser for the reference design.

  *-COND-TYPE = TOWER

- ***GPM per Ton***: For water-cooled chillers with, ACMs shall determine the condenser water flow as follows.

$$COMP-TO-TWR-WTR=\left[1+\frac{1}{\dfrac{\sum_{i=1}^{n}(COP_i\times SIZE_i)}{\sum_{i=1}^{n}SIZE_i}}\right]\times 2.4$$

where

COP_i = Coefficient of performance for chiller i

$$SIZE_i=\frac{Q_{des\_i}\times 12{,}000}{1{,}000{,}000}$$

n = Number of chillers

Modeling Rules for Reference Design (Existing Unchanged): ACMs shall model the existing chiller(s) using the actual data. If the actual data is not available, ACMs shall model the existing design the same as the reference design.

2.4.2.32 Number, Selection, and Staging of Chillers and Boilers

Description: The reference method accounts for staging of multiple cooling/heating units input for both the standard and proposed design.

DOE Keyword: INSTALLED-NUMBER
TYPE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model the number and staging of boilers and chillers as input and modeled by the user according to the plans and specifications for the building

Modeling Rules for Reference Design (New): The reference method selects the standard design chiller types as follows:

- Total cooling plant load < 150 tons: the standard system uses one (1) water-cooled scroll chiller.
- 150 tons ≤ total cooling plant load < 300 tons: the standard system uses one (1) water-cooled screw chiller.
- 300 tons ≤ total cooling plant load ≤ 600 tons: the standard system uses two (2) equally sized water-cooled centrifugal chillers.
- Total cooling plant load > 600 tons: the standard system uses a minimum of two (2) water-cooled centrifugal chillers but add machines as required to keep the maximum single unit size at or below 1000 tons.

ACMs shall bring up each chiller to 90 percent capacity prior to the staging of the next chiller. ACMs shall model the staged chillers in parallel.

The reference method selects the standard design boiler types as follows:

- Total heating plant load < 6,000,000 Btuh: the standard system uses one (1) atmospheric boiler (no combustion air fan).
- Total heating plant load ≥ 6,000,000 Btuh: the standard system uses two (2) atmospheric boilers (no combustion air fans) of equal size.

ACMs shall bring up each boiler to 90 percent capacity prior to the staging of the next boiler. ACMs shall model the staged boilers in parallel.

Modeling Rules for ACMs shall model the number and staging of boilers and chillers as input and modeled by the user according to the existing design of the central heating and

Reference Design (Existing Unchanged & Altered Existing): cooling plants.

2.4.2.33 Performance Curves for Electric Chillers

Description: The reference method models the performance curves of electric chillers as functions of variables such as the load, condenser water temperature, and flow rate.

The reference program uses a computer program to calculates custom regression constants for *electric chillers*. This program calculates the regression constants for performance curves according to the following rules, criteria, inputs, and outputs:

1. The curves are generated using ARI-550 or ARI-590 certified data.
2. The data have a minimum of 25 full-load points and 10 part-load points.
3. The full-load data represent a chilled water temperature range of (design-2) °F to (design+6) °F and a condenser water temperature range of 55°F to 85°F (or an outside dry-bulb temperature range of 45°F to 110°F for air-cooled equipment).
4. The part-load data represent unloading using both condenser relief and fixed design condenser temperature.
5. The rms error for power prediction on the data set is 5% or less.
6. The program report the APLV points as entered by the user and the chiller curve predicted performance at the same conditions.
7. The user cannot directly modify either the curve coefficients or the parameters including reference capacity, reference power, minimum unloading ratio, or maximum available capacity.

The program inputs are:

1. Make and model,
2. Chiller type,
3. Evaporator flow rate,
4. Evaporator bundle pressure drop,
5. Chiller design capacity,
6. Chiller design input power,
7. Chiller design chilled water supply temperature, and
8. Chiller design entering condenser water temperature (water-cooled), or
9. Chiller design outdoor dry-bulb temperature (air -cooled), and
10. Chiller APLV capacity,
11. Chiller APLV input power,
12. Chiller APLV chilled water supply temperature, and
13. Chiller APLV entering condenser water temperature (water-cooled), or
14. Chiller APLV outdoor dry-bulb temperature (air-cooled).

The program outputs are:

1. Predicted Coefficient Of Performance (COP) to within 5% of the

manufacturer's data,
2. Four predicted APLV points with a maximum rms error of 5 percent of the manufacturer's data, and
3. Regression coefficients.

For all of the chiller curves, there is a rated condition at which the curves are unity. These are a rated capacity and efficiency at full load and specific chilled water and condenser water supply temperatures. The default curves in DOE2.1E are all rated at 44°F chilled water supply temperature and 85°F condenser water supply temperature. These are the ARI 550-92 and 590-92 rating conditions. For custom curves these references will be $CHWS_{des\_i}$ and CWS_{des_i} (or OAT_{des_i} for air-cooled equipment).

Three curves are used to determine the performance of each chiller:

- EIR-FPLR — Percentage full-load power as a function of percentage full-load output.
- CAP-FT — Capacity correction factor as a function of chilled water supply temperature and condenser water supply temperature.
- EIR-FT — Efficiency correction factor as a function of chilled water supply temperature and condenser water supply temperature.

For air-cooled equipment the CAP-FT and EIR-FT curves are developed against the chilled water supply and outside air dry-bulb temperatures.

Each of the default curves are given in terms of regression constants (*a* through *f*). The regression equations have the following formats:

$$CAP\_FT = a + b \times CHWS + c \times CHWS^2 + d \times CWS + e \times CWS^2 + f \times CHWS \times CWS$$

$$EIR\_FT = a + b \times CHWS + c \times CHWS^2 + d \times CWS + e \times CWS^2 + f \times CHWS \times CWS$$

$$PLR = \frac{Q}{Q_{des} \times CAP\_FT(CHWS_{des}, CWS_{des})}$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2$$

Where:

PLR	Part load ratio based on available capacity (not rated capacity)
Q	Present load on chiller (in tons)
Q_{des}	Chiller design capacity (in tons)
CHWS	Chiller chilled water supply temperature °F
CWS	Entering condenser water temperature °F
$CHWS_{des}$	Chiller design chilled water supply temperature °F
CWS_{des}	Design entering condenser water temperature °F

For air-cooled equipment OAT is used in place of CWS in the CAP_FT and EIR_FT equations, where OAT is the outdoor dry-bulb temperature.

DOE Keyword: CURVE-FIT

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The reference program uses a computer program with capabilities, calculation criteria, and input and output requirements as described above for producing regression constants for performance curves of electric chillers specified on the plans and specifications for the building.

Default: Same regression constants and performance curves as those used for the reference design.

Modeling Rules for Reference Design (All): ACMs shall use the regression constants in Tables 2-10 through 2-16 for the performance curves of electric chillers.

Table 2-10: Default Capacity Coefficients for Electric Air-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.40070684	0.57617295	-0.09464899	N/A
b	0.01861548	0.02063133	0.03834070	N/A
c	0.00007199	0.00007769	-0.00009205	N/A
d	0.00177296	-0.00351183	0.00378007	N/A
e	-0.00002014	0.00000312	-0.00001375	N/A
f	-0.00008273	-0.00007865	-0.00015464	N/A

Table 2-11: Default Capacity Coefficients for Electric Water-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.36131454	0.58531422	0.33269598	-0.29861976
b	0.01855477	0.01539593	0.00729116	0.02996076
c	0.00003011	0.00007296	-0.00049938	-0.00080125
d	0.00093592	-0.00212462	0.01598983	0.01736268
e	-0.00001518	-0.00000715	-0.00028254	-0.00032606
f	-0.00005481	-0.00004597	0.00052346	0.00063139

Table 2-12: Default Efficiency EIR-FT Coefficients for Air-Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.99006553	0.66534403	0.13545636	N/A
b	-0.00584144	-0.01383821	0.02292946	N/A
c	0.00016454	0.00014736	-0.00016107	N/A
d	-0.00661136	0.00712808	-0.00235396	N/A
e	0.00016808	0.00004571	0.00012991	N/A
f	-0.00022501	-0.00010326	-0.00018685	N/A

Table 2-13: Default Efficiency EIR-FT Coefficients for Water-Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	1.00121431	0.46140041	0.66625403	0.51777196
b	-0.01026981	-0.00882156	0.00068584	-0.00400363
c	0.00016703	0.00008223	0.00028498	0.00002028
d	-0.00128136	0.00926607	-0.00341677	0.00698793
e	0.00014613	0.00005722	0.00025484	0.00008290
f	-0.00021959	-0.00011594	-0.00048195	-0.00015467

Table 2-14: Default Efficiency EIR-FPLR Coefficients for Air-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.06369119	0.11443742	0.03648722	N/A
b	0.58488832	0.54593340	0.73474298	N/A
c	0.35280274	0.34229861	0.21994748	N/A

Table 2-15: Default Efficiency EIR-FPLR Coefficients for Water-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.04411957	0.08144133	0.33018833	0.17149273
b	0.64036703	0.41927141	0.23554291	0.58820208
c	0.31955532	0.49939604	0.46070828	0.23737257

2.4.2.34 Cooling Towers

Description: The ACM cooling tower model must, at a minimum, incorporate the following characteristics:

- *Open circuit:* Condenser water is cooled by evaporation by direct contact with ambient outdoor air stream.
- *Centrifugal fan:* A centrifugal fan provides ambient air flow across evaporative cooling media.

- *Staging of Tower Cells:* Capacity is varied by staging of tower cells.
- *Electrical input ratio:* The ratio of peak fan power to peak heat rejection capacity at rating conditions.

DOE Keyword: TYPE
INSTALLED-NUMBER
TWR-CELL-CTRL
TWR-CELL-MIN-GPM
MIN-RATIO
EIR
TWR-DESIGN-WETBULB
TWR-DESIGN-APPROACH
TWR-SETPT-T
TWR-CAP-CTRL

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model cooling towers as follows:

- ***Sizing.*** ACMs must autosize the cooling tower using the following parameters:

    1. Design Wet-Bulb Temperature using 0.5% design wet-bulb column of ASHRAE publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982.

    2. Design Approach Temperature as input by the user according to the plans and specifications for the building.

    3. Number of Tower Cells as input by the user according to the plans and specifications for the building.

    If the number of cells is specified, then

    INSTALLED-NUMBER = # of cells input by the user

    If the number of cells is not specified, then

$$INSTALLED-NUMBER = \frac{\sum_{i=1}^{n} Q_{des\_i}}{1000}$$

    where:

    Q_{des_i} = Chiller design capacity (in tons)
    n = Number of chillers

- ***Staging of Tower Cells.*** ACMs shall have a control scheme to use the maximum number of cells possible and stage on as many cells as can be staged to keep the flow rate per cell above the minimum allowable.

- ***Fan Control.*** ACMs shall accept input by the user for the cooling tower fan control according to the plans and specifications for the building.

- ***Condenser Water Set-point Control.*** ACMs shall use a set-point temperature of 70 ^{o}F.

- ***Electrical Input Ratio.*** ACMs shall calculate the Electrical Input Ratio (EIR) as follows:

$$E - I - R = \frac{HP_{CT} \times 2.545}{\sum_{i=1}^{n}(Q_{des\_i} \times 12 + P_{des\_i} \times 3.413)}$$

where:

HP_{CT} = Cooling tower nameplate horsepower per cell
Q_{des_i} = Chiller design capacity (in tons)
P_{des_i} = Chiller design input power (in kW)
n = Number of chillers

Modeling Rules for Reference Design (New): The reference method uses a single cooling tower with the following features for the standard design system:

- ***Sizing.*** ACMs must autosize the cooling tower using the following parameters:

  1. Design Wet-Bulb Temperature using 0.5% design wet-bulb column of ASHRAE publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982.

  2. Design Approach Temperature of 10 ^{o}F.

  3. Number of Tower Cells equal to the proposed design. If the proposed design uses air-cooled chillers (no cooling towers), the number of Tower Cells shall be equal to the number of chillers in the reference design.

- ***Staging of Tower Cells.*** The reference design shall use a control scheme to use the maximum number of cells possible and stage on as many cells as can be staged to keep the flow rate per cell above 50 percent of maximum.

- ***Fan Control.*** The reference design shall use a two-speed fan control system.

  TWR-CAP-CTRL = TWO-SPEED-FAN

- ***Condenser Water Set-point Control.*** The reference design shall use the same set-point temperature as the proposed design.

- ***Electrical Input Ratio.*** The reference design shall use an EIR of 0.013.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall model the existing cooling tower(s) using the actual data. If the actual data is not available, ACMs shall model the existing design the same as the reference design.

2.4.2.35 HVAC Distribution Efficiency of Packaged Equipment

Description: ACMs shall be able to determine the efficiency of ducts in the unconditioned spaces between insulated ceilings and roofs.

ACMs shall require the user to enter the duct insulation R-value, the number of building stories, and whether or not the ducts will be sealed and tested for reduced duct leakage.
ACMs shall be able to reproduce the duct efficiencies in Appendix H

DOE Keyword: None. Duct efficiency divisors for COOLING-EIR, COOLING-EIR-SEER and HEATING-HIR will be calculated by means of the equations in Appendix G.

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall calculate the duct efficiency for the *Proposed Design* as specified in Appendix G based on the user inputs specified in this section. The ACM shall require the user to input duct R-value, the number of building stories and whether or not credit for reduced duct leakage will be claimed and tested.

Default: Duct R-value of 4.2 [h^{o}F ft^{2}/Btu] and duct leakage of 22% of fan flow. Number of stories is defaulted to one (1).

Duct Sealing Caution Warning on PERF-1 if HVAC Distribution Efficiency Option is claimed. Warning must include minimum qualification criteria described in Appendix G, Section 4.3.4

Modeling Rules for Reference Design (New): The ACM shall calculate the duct efficiency for the *Reference Design* as specified in Appendix G based on the default values specified in this section. The Reference Design shall assume the default values for the duct efficiency inputs (Duct R-value = 4.2, Duct Leakage = 22%) except that the number of stories shall be the same as for the Proposed Design.

Modeling Rules for Reference Design (Existing Unchanged & Altered Existing): ACMs shall model the same distribution system for the Reference Design as for the Proposed Design

2.5 Service Water Heating - Required Capabilities

ACMs must be capable of modeling service water heating systems for nonresidential and high-rise residential buildings. The service water heating system must be modeled if it is part of combined hydronic system that serves both space and service water heating demands. ACMs are required to model independent systems for only service water heating. ACMs must require the user to identify if service water heating is included in the performance compliance submittal. ACMs must also require the user to identify the type of service water heating systems as described below under *Nonresidential Service Water Heating* and *Residential Service Water Heating*

2.5.1 Nonresidential Service Water Heating

ACMs must be able to accept inputs to distinguish electric or gas water heating source energy and must either assume part-load performance curves for the types of water heaters allowed to be entered OR allow entry of an efficiency (some sort of annual or seasonal efficiency is preferred but a steady state efficiency is acceptable) for the water heating system. The ACM must be able to accept inputs from the user for a recirculating water heating system or an electrically traced (electric tape) water heating system.

The standard water heating system for either of these two systems is a water heating system with all hot water pipes insulated and a gas boiler with an efficiency of 80%. For hotels and high-rise residential buildings, the standard water heating system is a recirculating system.

Water heating shall be modeled using the hourly loads for each occupancy as shown in Tables 2-1 or 2-2, multiplied by the fraction of load in each hour shown in the water heating schedule in Tables 2-4, 2-5, 2-6, or 2-7. These loads shall be combined for each zone to develop a total building water heating load for each hour. Each water heater shall be assigned an individual load, and shall be modeled independent of other water heaters. The ACM shall convert electric energy to Btu/hr at the conversion rate of 10.239 Btu per watt-hour.

2.5.2 Energy Use of Water Heaters for Nonresidential Buildings and Residential Buildings with Combined Hydronic Systems

The hourly water heating energy use shall be determined from Equation 2.5.1.

$$WHEU_n = SRL \times F_{whpl(n)} \times DHWHIR \times HIRCOR \qquad \textbf{Equation 2.5.1}$$

Where:

$WHEU_n$ = Water heating energy use for the n^{th} hour

$F_{whpl(n)}$ = Hourly load multiplier for the n^{th} hour from Table 2-4, 2-5, 2-6, or 2-7

SRL = Standard Recovery Load in Btu/hr, derived from the loads per person shown in Table 2-1 or 2-2 for the occupancy served by the water heater. If a water heater may serve more than one occupancy, the load should be weighted by the number of square feet in each occupancy served by the water heater.

$DHWHIR$ = Heating input ratio of the water heater(s) which is equal to the inverse of the recovery efficiency (RE) or thermal efficiency (TE). The recovery efficiency for electric water heaters is 0.98.

$HIRCOR$ = Part-load correction factor

HIRCOR is determined from the following procedure, given in the form of a DOE 2.1 curve fit instruction:

DHW-HIR-FPLR = ACM-DHW-CRV ..
ACM-DHW-CRV = CURVE-FIT
TYPE = LINEAR
COEFFICIENTS = (DHW-A,DHW-B) ..

These commands yield an equation for HIRCOR of:

$$HIRCOR = (DHW\text{-}A) + (DHW\text{-}B) \times PLR$$

Where:

$$DHW - A = \frac{STBY}{INPUT}$$ **Equation 2.5.2**

$$DHW - B = \frac{(INPUT \times RE^*) - STBY}{SRL}$$ **Equation 2.5.3**

* or Thermal Efficiency (*TE*)

PLR_n = Part-load ratio for the n^{th} hour and must always be less than 1. PLR_n is calculated from the following equation:

$$PLR_n = \frac{SRL \times F_{whpl(n)}}{INPUT \times RE^*}$$ **Equation 2.5.4**

* or Thermal Efficiency (*TE*)

INPUT = The input capacity of the water heater expressed in Btu/hr.

STBY = Hourly standby loss expressed in Btu/hr.

For storage type water heaters, not in the scope of Covered Consumer Products as defined in the Title 10 or the Code of Federal Regulations, Part 430;

$$STBY = 453.75 \times S \times VOL$$ **Equation 2.5.5**

Where:

S = The standby loss fraction published in the Commission's Directory of Certified Water Heaters,

VOL = The actual storage capacity of the water heater as published in the Commission's Directory of Certified Water Heaters,

For storage type water heaters that are covered consumer products, the standby loss shall be calculated with the following equation.

$$STBY = \frac{1440.104 \times \left(\frac{1}{EF} - \frac{1}{RE\,*} \right)}{\left(1 - \frac{1701.941}{\left(INPUT \times RE\,* \right)} \right)} \qquad \textbf{Equation 2.5.6}$$

* or Thermal Efficiency (*TE*)

Where:

EF = Energy Factor

For instantaneous water heaters that are not Covered Consumer Products,

STBY = PILOT

Where PILOT is the pilot light energy use in Btu/hr

Required inputs and standard and proposed design assumptions depend on the type of water heater and whether or not it is a DOE covered consumer product.

2.5.2.1 DOE Covered Water Heaters

Description: ACMs must require the user to enter fuel type (electricity or gas), input, volume, energy factor, recovery efficiency or thermal efficiency, and quantity for DOE covered storage-type water heaters.

DOE Keyword: DHW-TYPE
DHW-SIZE
DHW-EIR
DHW-EIR-FT
DHW-EIR-FPLR

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall assume fuel type, input, volume, energy factor, recovery efficiency or thermal efficiency, and quantity as input by the user and as shown in the construction document for the building.

Modeling Rules for Reference Design (All): The standard design shall assume fuel type, input, volume, recovery efficiency or thermal efficiency, and quantity identical to the proposed design. The standard design shall assume an energy factor, calculated as a function of the volume, according to equations found in either Section 111 or 113 of the Building Energy Efficiency Standards~~Table F-5 of the Appliance Efficiency Regulations, CEC Publication #P400-92-029, dated September 1992~~.

2.5.2.2 Water Heaters not Covered by DOE Appliance Standards

Description: ACMs must require the user to enter fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity for all storage type water heaters that are not covered by DOE appliance standards.

DOE Keyword: DHW-TYPE
DHW-SIZE
DHW-HEAT-RATE
DHW-EIR
DHW-EIR-FT
DHW-EIR-FPLR
DHW-LOSS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The proposed design shall assume fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity as input by the user and as shown on the construction documents for the building.

Modeling Rules for Reference Design (All): The standard design shall assume fuel type, input, volume and quantity that are identical to the proposed design. The standard design shall assume recovery efficiency or thermal efficiency and standby loss ~~according to~~ as specified in either Section 111 or 113 of the Building Energy Efficiency Standards~~the applicable minimum requirements of Title 24, Part 1.~~

2.5.2.3 Boilers

Description: If a boiler (or boilers) serve both space and service water heating systems, the ACM shall assign space heating and recovery loads to the boiler for both the standard and proposed designs. Boilers shall be simulated as described in Section 2.4.2.14 or 2.4.2.15, whichever is applicable.

2.5.2.4 Unfired Indirect Water Heaters (Storage Tanks)

Description: ACMs shall simulate jacket losses and effective recovery efficiency for unfired indirect water heaters and storage tanks. Jacket losses shall be calculated using the following equation:

$$JL = \frac{117.534VOL^{0.66} + 99.605VOL^{0.33} + 21.103}{REI} + 61.4$$

Equation 2.5.7

Where:

JL = Hourly jacket loss in Btu
VOL = Volume of indirect heater or storage tank in gallons
REI = R-value of exterior insulating wrap

The adjusted hourly recovery load seen by the primary water heating devices described above (e.g. water heater or boiler) shall be calculated according to Equation 2.5.8

$$PARL_n = \frac{SRL \times F_{whpl(n)} \times JL}{0.98}$$

Equation 2.5.8

Where:

$PARL_n$ = Adjusted recovery load seen by the primary water heating device for the nth hour

DOE Keyword: DHW-LOSS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: ACMs shall assume indirect water heaters with volume and REI as input by the user and as shown in the construction documents for the building. ACMs must not allow the user to enter an REI of less than 12.

Modeling Rules for Reference Design (All): If an indirect water heater is input as part of the proposed design, that standard design shall assume an indirect heater with the same volume as the proposed design and REI of 12.

2.5.3 Residential Water Heating Calculation Methods

For high-rise residential buildings, ACMs shall calculate the energy consumption of the proposed water heating system(s) and the water heating energy budget in accordance with Section 151(b)(1) of the standards. Alternatively, users may show service water heating compliance using the prescriptive requirements of Section 151(f)(8~~9~~) of the standards.

2.6 Weather Data

The energy budget and compliance runs must use a form of the weather data in the Commission's official sixteen (16) climate zone hourly weather files. The reference method uses a form of this data that is adjusted for local ASHRAE design data extremes. These files are available from the Commission in the WYEC2 (Weather Year for Energy Calculations) format recognized by ASHRAE and in DOE 2.1E packed weather data format. The reference method computer program for adjusting the climate zone weather data for local ASHRAE design data is also available from the Commission. Temperatures in the WYEC2 files for the sixteen climate zones have been adjusted to the average means and extremes of the weather data of the reliable substations in each climate zone. See *Climate Zone Weather Data Analysis and Revision Project*, Final Consultant Report, CEC Publication # P400-92-004, for more detail.
The WYEC2 data may be adjusted for local conditions, condensed, statistically summarized or otherwise reduced, as long as:

(a) The weather data used to derive the simplified or reduced data is the Commission's official hourly weather data; and,

(b) The ACM program meets all of the certification tests using the reduced weather data.

Whatever weather data and/or weather data reduction methods are used, approval of the ACM for compliance purposes with the standards is contingent upon the fact that approved weather data will be used for all compliance runs. The Commission must be able to verify that the proper weather data is being used by building permit applicants.

The official weather data for energy compliance is available from the Commission in a form suitable for 3.5" high density IBM PC-formatted diskettes. There are 16 climate zones, each with an 8760 hourly records containing raw data on a variety of ambient conditions such as:

- Dry-bulb temperature
- Wet-bulb temperature
- Wind speed and direction
- Direct solar radiation
- Diffuse radiation

Each climate zone file includes the non-temperature data of a hypothetical city whose annual climate data has been judged representative of the construction locations within that zone. The values listed by climate zone for each climate zone in Table 2-16 must be used for any given climate zone if the ACM does not automatically make local city weather adjustments to the files.

As indicated above the reference method uses local city ASHRAE design data to adjust the climate zone weather data. These adjustments customize the temperature data, especially the extremes, to conform to the ASHRAE design data statistics for the city in question. This makes the energy calculations more realistic for energy compliance simulations. These adjustments are described in more detail in Appendix C.

Table 2-16: California Climate Zone Summary

Climate Zone	Latitude (Degree)	Longitude (Degree)	Elevation (Feet)
1	40.8	124.2	43
2	38.4	122.7	164
3	37.7	122.2	6
4	37.4	122.4	97
5	34.9	120.4	236
6	33.9	118.5	97
7	32.7	117.2	13
8	33.6	117.7	383
9	34.2	118.4	655
10	33.9	117.2	1543
11	40.2	122.2	342
12	38.5	121.5	17
13	36.8	119.7	328
14	35.7	117.7	2293
15	32.8	115.6	-30
16	41.3	122.3	3544

2.7 Required Standard Reports

All nonresidential ACMs must be able to automatically produce certain reports in a standard format that has been approved by the Commission, the sample forms in Appendix E of this manual meet this requirement when a building is determined to comply with the standards. These standard reports are required to enable building officials to quickly and accurately evaluate the results of the various ACMs with limited additional training. The required output forms are intended to be as similar as possible to the forms used in the prescriptive compliance approach so that those who are familiar with the prescriptive forms will easily be able to find information on the output from the performance approach. In fact, with the exception of the PERF-1 form, other forms are nearly duplicates of prescriptive forms or full page portions of the prescriptive forms. To allow the optional capabilities of Partial Compliance, Alterations, or automatic modeling of Additions Modeled with the Existing Building, there are distinct additional forms describing existing building components and systems that must be printed separately than the forms describing the altered or new building components and systems and must have **ALL** text in lowercase type.

In the sample form formats in Appendix E, the first pages (signature pages) of the prescriptive ENV-1, LTG-1, and MECH-1 certificates of compliance are consolidated on the first page of the PERF-1 form. The PERF-1 is the Certificate of Compliance for the performance approach and all three parts of the PERF-1 form (at least three pages) must be included as part of the plans. All forms with the term "Certificate of Compliance" in the header of the sample forms must be attached as part of the plans submittal. Typically the pages of these forms are adhered to a plan sheet and submitted with the plans. These forms are considered to be an integral part of the plans and are to be recorded in exactly the same manner as a set of plans and retained for the same period of time as official records of the plans.

An ACM must be able to print standard reports/compliance forms (formats approved by the Commission) when a modeled building design complies with the standards as described in the reference procedure. The purpose of compliance output is to facilitate enforcement of the standards by providing the local enforcement agency with the precise amount of information needed to accurately verify compliance with the energy efficiency standards and to verify conformity of the building design with the modeled or simulated building. Too much or too little information obstructs enforcement. Secondary or irrelevant information confuses the building official or wastes his time. On the other hand, a lack of relevant information may lead to enforcement errors or encourage cheating. To be approved for compliance use, an ACM cannot allow the user to directly select the compliance forms to be printed. Each ACM must determine the compliance output based on the user's input description of the building and the type of compliance run for the building.

In addition, **an ACM must not be able to print compliance form formats when a modeled proposed building design does not comply with the building standards** - i.e. when a proposed building design modeled by an approved ACM in accordance with the reference procedure has an estimated energy budget that exceeds the estimated energy budget of the standard building design, compliance forms must not be printed, displayed on screen, or written on disk. An ACM is only required to provide a minimum of diagnostic results for buildings that DO NOT COMPLY. This minimum information includes the energy use components of the energy budget in source kBtu per ft^2 per year and the total source energy use budget for both proposed and standard building designs and the compliance margin. An ACM may also provide other diagnostic output when a building fails to comply, but all diagnostic output must be so different from the compliance output (in format, layout, and content) that a reasonable person could not confuse diagnostic output with compliance output. Each page or display screen of noncompliance output must indicate: DIAGNOSTIC OUTPUT ONLY - NOT FOR COMPLIANCE USE. An ACM that has noncompliance output **MUST NOT** report runcodes, initiation times, or total page counts on noncompliance output or display. Similarly, noncompliance output **MUST NOT** use approved form headers or header information at the top of a page. Resemblance of noncompliance output to compliance forms is sufficient grounds for rejection of the ACM for use as a compliance computer program.

Compliance output is highly restricted in quantity and format. All non-default inputs **must** be reflected directly in the output. This can also be accomplished by changes in directly-related output values and the forms reflecting those changes **must** be printed when any compliance output forms are selected. Exceptional user entries or values outside of "normal" ranges must be printed and must be clearly flagged in the output so that the plan checker and field checker can and will readily note these user entries or values. Exceptional user entries include such entries as tailored lighting and modifications to certain default values specified herein. When the user enters such exceptional input in a compliance run, the ACM must automatically print the forms containing such user inputs. Exceptional conditions must be indicated on the PERF-1 form as part of the special conditions verification checklist for the plan checker and field inspector.

This verification list must command the attention of anyone reviewing the output and must be included with all performance compliance submittals even if no exceptional conditions are reported. In particular exceptional inputs **must** be reflected on the relevant ENV, MECH, or LTG forms **and** the PERF-1 Form and the forms showing these exceptional entries **must** be printed when any compliance output forms are selected. Typically exceptional conditions or use of non-default values require additional backup information to be submitted. This information may be attached to the compliance form output submittal or included as additional ACM printed information following the package of approved compliance forms.

For a compliance documentation run, the ACM must automatically determine the forms to be printed and the total number of pages (T) required to print those forms and must print exactly that number of pages and all ACM-determined forms. The determination of the total number of pages (T) must be made based on the user's description of the scope of compliance, the building characteristics, and the user's selection of a compliance run. ACMs may not allow the user to select specific forms to be printed in a compliance run (as distinguished from a diagnostic run) where printed or disk compliance output is requested. Each page (N) of the required output must indicate Page N of T in the page header, the unique compliance runcode and the initiation time of the compliance run. The PERF-1 must list or indicate all of the forms required for a valid submittal, including those required to be done by hand.

ACMs must interlock program input and compliance output to prevent any modifications to input files that is inconsistent with the compliance run and compliance output for the unmodified building input file. At a minimum, any alterations in the user input must result in a new run initiation time and runcode on any compliance output generated thereafter and a completely new full set of compliance output for the type of compliance selected must be printed when the ACM user has selected compliance output. In other words the compliance output is interlocked to a specific set of user input, this may be done by having a compliance runs use only information from a specific SAVED user input file or by having the ACM automatically save the input file as a part of the compliance run sequence. The ACM vendor is encouraged to restrict compliance output to be only generated from saved input files whose characteristics (size, creation date, and name) are indicated on the PERF-1 form.

User inputs must appear on the ACM reports but the reporting of prescribed input assumptions is usually unnecessary since ACMs are required to automatically use these inputs. The Commission does not want to encourage debate on prescribed assumptions at the local enforcement agency. Commission staff workshops and Commission hearings for changes to this manual are the appropriate forums for debating such ACM restrictions. ACMs are only allowed to report the prescribed inputs or assumptions that are required by the building official to verify compliance. When inputs with standard defaults are modified by the user, the modified value must be distinctly identified (flagged) in the standard reports to alert the local enforcement agency of an exceptional condition for compliance so that it can be verified by the code official that the alternate value is acceptable for compliance and corresponds to special features of the building documented in the plans and included as part of the building itself.

The format of the standard reports is designed to provide consistency with the prescriptive forms to reduce the amount of training required for the staff of local enforcement agencies. Consistency amongst the forms used for the prescriptive and performance approaches and amongst approved ACMs also fosters better and easier enforcement. Thus a standard format and style for reporting building energy efficiency compliance, reasonably consistent with the prescriptive forms in the Nonresidential Manual is required for all ACMs. However, minor modifications to the reports may be allowed in order to accommodate optional special modeling capabilities of an ACM. All additional reports and printed output information must be approved through the certification process.

To accommodate the optional capabilities of partial compliance and modeling additions with the existing building and alterations and deter circumvention of the standards, **all ACMs MUST report all new or altered user-entered building components and descriptive information completely in UPPERCASE type.** ACMs with the capabilities for partial compliance, automatic modeling of additions with the existing building or modeling alterations in an existing building **MUST report all information on existing, previously-approved building components that are not altered in lowercase type. For partial compliance the ACM must produce the special EXISTING-ENV forms for the existing envelope.** Partial compliance applicants with building envelopes approved within the previous two years must supply envelope compliance information along with the EXISTING-ENV forms. This is to insure that the local enforcement agency can readily determine that the existing envelope has indeed complied and that the use of existing building components that do not have to meet the requirements of the building energy efficiency standards and distinguish these modeled components from those that are new or have been altered.

The required reports shown in this section follow a format that can be reproduced with simple ASCII characters on any standard printer. The format is 75 characters per line and 60 lines per page. Using a standard 10-character-per-inch typeface (such as Courier), this format translates into a 0.5" margin top, bottom, left and right on letter-size (8.5"x11") paper.

2.7.1 Certificate of Compliance Form(s)

(PERF-1, ENV-1, EXISTING-ENV, LTG-1, EXISTING-LTG, MECH-1, and EXISTING-MEC)

The first standard report that must be produced by all ACMs is the Certificate of Compliance which is divided into four sections: the Performance Summary (PERF-1 forms), Envelope (ENV-1 form), lighting (LTG-1 form) and mechanical (MECH-1 forms). The Certificate of Compliance is required by Title 10, Section 1403(a)2.A, B and C(2) of the California Code of Regulations. For the performance approach all signature blocks for the Certificate of Compliance are combined onto the first page of the PERF-1 compliance output form. Normally all of these signature blocks must be signed by the responsible designers. However, when an ACM is approved for optional partial compliance features and the partial compliance option is being used, only one or two of the signature blocks need be filled in. However, when this occurs the signatures must be consistent with the type of partial compliance indicated on the Certificate of Compliance - PERF-1 forms and information reported on other output reports.

The PERF-1 must list all optional capabilities utilized by the user and must identify the zone(s), system(s) and/or plant(s) to which the optional capabilities apply. The PERF-1 must also itemize the use of any of the following exceptional building compliance features on the exceptional conditions checklist, identifying the zone(s), systems(s) and or plant(s) to which the feature(s) apply.

- Absorptance < 0.40
- Exterior Surface Emmissivity Different from DOE2.1E defaults.
- Any User-Defined Materials, Layers, Constructions, Assemblies
- Window-wall-ratio > 0.40
- Skylight-roof-ratio > 0.05
- Solar Heat Gain Coefficient (vertical or horizontal) < 0.40
- Fenestration ~~U-value~~U-factor (vertical or horizontal) < 0.50
- Use of "Industrial/Commercial Work - Precision" occupancy
- Process Fan Power
- Process Loads
- Tailored lighting input
- Lighting control credits
- Electric Resistance Heating or Reheating
- Hydronic (water source heat pumps)
- Economizer installed on equipment below 75,000 Btuh and 2500 cfm
- Variable speed drive fans
- Other high efficiency fan drive motors
- Verified sealed ducts in ceiling/roof spaces
- Any optional capabilities used

One consequence of **partial compliance** is that fewer forms are required and fewer forms will be printed. The forms, the total number of pages, and the runcode and initiation time printed on each of the forms must be consistent with the fewer number of pages allowed for partial compliance.

The PERF-1 form must also provide information on the service water heating system, including the system type, the efficiency of the water heating system or its components, pipe insulation specifications, and the fuel source used for service hot water.

When partial compliance is used or an addition is modeled with an existing building and its existing building components, these components must be flagged on the exceptional conditions checklist on the PERF-1 forms and the relevant EXISTING forms must be produced.

[SAMPLE COMPLIANCE FORMS ARE SHOWN IN APPENDIX E.]

2.7.2 Supporting Compliance Forms

The second type of standard reports that must be produced by all ACMs are the Supporting Compliance Forms including the ENV-2, LTG-2, MECH-2, MECH-3 and MECH-4 forms. Examples of versions of these forms are in Appendix E.

The ACM may also have algorithms or subroutines for prescriptive compliance and generate prescriptive compliance forms ENV-3, LTG-3, and LTG-4 automatically. If so, the pages of these forms must be tabulated and counted along with the performance forms for total page counts and verification on the PERF-1 form. If these forms are not used for a given performance compliance run, the ACM must not be able to print the forms with that performance compliance run. If they are utilized for a particular performance compliance run, the ACM must print them with the appropriate runtime and runcodes and correlate them with information on the PERF-1 form.

[SAMPLE COMPLIANCE FORMS ARE SHOWN IN APPENDIX E.]